REPORTS ON ANDROSCOGGIN RIVER, MAINE & NEW HAMPSHIRE

PRELIMINARY REPORT ON MARCH 1936 FLOOD	MARCH 30, 1936
REVIEW REPORT (DISTRICT)	DECEMBER 30, 1936
REVIEW REPORT (DIVISION)	AUGUST 25, 1937
PRELIMINARY EXAMINATION (DISTRICT)	OCTOBER 11, 1937
PRELIMINARY EXAMINATION (DIVISION)	DECEMBER 17, 1937

WAR DEPARTMENT
United States Engineer Office
13th Floor, Custom House
Boston, Mass.

March 30, 1936

Subject: Preliminary Report on 1936 Flood In Androscoggin River Basin.

To: The Division Engineer, North Atlantic Division, New York, N. Y.

1. The recent floods in the Androscoggin River Basin, Maine and New Hampshire, have not only been unprecedented in magnitude, but are far beyond anything anticipated by the various engineers who have made investigations and reported on the river in the past. This situation, of course, requires a revision of the report previously submitted by the District Engineer on this river July 12, 1929, under the provisions of House Document No. 308, 69th Congress, 1st Session, and printed in House Document No. 646, 71st Congress, 3rd Session. Reference is made to this document for description and maps of the area.

2. This preliminary report deals with three principal factors covered in the above mentioned report which, it is now apparent, are substantially different from the data given in the original report. These three factors are:

a. The hydraulic aspects of the problem.

b. The damage which might result from a great flood.

c. The revised conclusions which can be made tentatively at this time.

3. What this flood has meant as an experience beyond all calculations previously made can best be shown by direct comparison with the greatest floods previously recorded. The two tables below show the gauge heights at available stations on the river and the flood discharge at important stations. Two charts which accompany this report present the same information in graphic form.

COMPARATIVE FLOOD HEIGHTS AND DISCHARGES
AT IMPORTANT STATIONS IN ANDROSCOGGIN RIVER BASIN,
MAINE AND NEW HAMPSHIRE

TABLE I

FLOOD HEIGHT IN FEET

LOCALITY	PREVIOUS GREAT FLOODS IN ORDER OF MAGNITUDE			FLOOD OF 1936
	1st	2nd	3rd	
*Gulf Island above Lewiston	4.87			10.55
*Rumford, Me.	8.0	5.7	5.5	10.5
**Gorham, N. H.	8.38			9.94

*Height above crest of dam.

**Height above normal.

TABLE II

DISCHARGE IN CUBIC FEET PER SECOND

LOCALITY	PREVIOUS GREAT FLOODS IN ORDER OF MAGNITUDE			FLOOD OF 1936
Bu	1st	2nd	3rd	
1 Gulf Island above Lewiston	71,500	65,000	60,000	200,000
2 Rumford, Me.	55,200	50,000	38,000	75,000
3 Gorham, N. H.	13,900	9,920	5,380	20,000

NOTE: Period covered by flood records used.
1. 1927 to date.
2. 1892 to date.
3. ------

4. Newspaper reports and other sources have estimated the damage in the Androscoggin Valley as high as $7,000,000. However, a preliminary compilation from the data which could be collected in such a short time from public utility, municipal, and industrial authorities, together with estimates of damages ascertained by personal reconnaisance by representatives of this office reveals that these reports have in many cases been greatly exaggerated. Nevertheless, the total damage from the recent flood is very great and is probably about $3,000,000. Some conception of what this flood has meant to the inhabitants of the Valley and to the works of man located therein, can be gained from the selected photographs which accompany this report. The major classifications into which these items may be grouped are indicated in Table III, below:

TABLE III

PRELIMINARY ESTIMATE OF TOTAL FLOOD DAMAGE

Item	Estimated Damage
Highway Bridges	$ 500,000
Highways	800,000
Railroads	400,000
Public Utilities	100,000
Public Property	100,000
Private Property	1,100,000
	$3,000,000

5. Conclusions

The probability that the conditions responsible for the 1936 flood will be repeated in the near future is slight. Floods of this magnitude would probably not occur oftener than once in 500 to 1000 years. Nevertheless, it is possible that a flood of equal, or greater, magnitude will occur next year or for several successive years. In view of the extensive damage and the possibility that the damage would be equally great in any repetition of the 1936 flood heights it is believed that further studies of flood control measures, such as the reservoir suggested in the report mentioned in paragraph 1, above, are justified. It is impossible to ascertain without further study what preventive measures, if any, may be taken because the available data are incomplete. Further surveys and studies, consideration being given to the possible results had the second 1936 flood followed the first more closely, is recommended. It is estimated that $75,000 will be required for such a survey.

John J. Kingman
Colonel, C orps of Engineers
District Engineer

170.1

NAD 73/43

Subject: Preliminary Report on 1936 Flood in Androscoggin River basin

1st Ind.

Office, Division Engineer, NORTH ATLANTIC DIVISION, NEW YORK CITY, April 1, 1936
To the Chief of Engineers, U. S. Army

1. It is recommended that a preliminary survey be made, such preliminary survey to include, (a) the determination of basic hydrologic data for the flood control system, (b) the geographical distribution and amounts of damages due to 1936 and prior floods, (c) the main elements of an integrated system, to include, primarily, well distributed reservoirs or detention basins through the watershed, controlling at least 30 per cent thereof, (d) the location of all sit es for reservoir structures or detention basins, as appear to be economical, and such levees as may be necessary or desirable in special cases to supplement the reservoir system as a general flood protection measure, (e) the general characteristics of such structures, including overall volume and the flood reducing effects thereof, and (f) estimates of cost, to include separately; construction, relocation of railroads and utilities, rights of way and land, and highway relocation. In my opinion, only the first two of these should constitute a cost to the United States.

The location and characteristics of all structures will be sufficiently well reported that priority can be quickly determined so that any sum made available for construction can be expended on those which offer the maximum flood control benefits.

Items (e) and (f) of the preliminary survey, as defined above, will be predicated upon certain guides based on past experience, which this office will furnish the District Engineer in order to save the time that would be required for their accurate and scientific determination.

An example of what is meant by such a guide based on experience is the following for the determination of the minimum capacity and safe height of reservoirs formed of earthen dams: All earth dams to have five-foot freeboard with fourteen-inch run-off in ten days varying in accordance with the normal hydrograph of the reservoir basin, approximately one-half of which is to be cared for by volume of reservoir at spillway lip plus discharge through outlets, and remainder by water over spillway, the surcharge on spillway crest to be ordinarily not in excess of ten feet. The capacity of the spillway will further be sufficient to pass, with a five-foot freeboard, the maximum flood run-off hydrograph of record for a basin of equivalent area in the watershed assuming the dam full to the spillway crest. The foregoing is for drainage areas of about 200 square miles or less and may be modified for larger areas.

Another such major guide is to assume for earthen dams that cost of dam and all appurtenances, and including overhead, will approximate $1.30 per cubic yard of the overall volume included in dams and spillway - providing work is done by contract in the most economical modern manner, and $18.00 for concrete dams of gravity section.

2. Such preliminary survey can be prepared in four months; the more formal survey report to follow.

3. If the entire sum requested by the District Engineer cannot be allotted at this time, a reasonable proportion thereof is requested in order that field work on a proper scale be started at once.

GEO. R. SPALDING
Colonel, Corps of Engineers,
Division Engineer.

CONTENTS

REVIEW REPORT ON ANDROSCOGGIN RIVER, MAINE

AND NEW HAMPSHIRE

Syllabus

The conclusions and recommendations of the report under review are basically sound concerning navigation, irrigation and power development. Improvement of the river for navigation is unwarranted at the present time. Irrigation is unnecessary. Power from existing installations is sufficient for present demands and the power companies are prepared to develop additional potential hydro-electric sites when the demand warrants.

Study of additional information available as a result of the unprecedented March, 1936, floods and investigations initiated thereafter indicate that some revision of the conclusions concerning flood control contained in the report under review is necessary. The District Engineer concludes, from studies of possible methods of flood control, that the plan he proposes, construction of four reservoirs, or any lesser number selected therefrom, is practicable but not economically feasible at the present time. In order to control development within the potential reservoir areas to permit their construction when justified by increased development of the basin, acquisition of these reservoir sites as state or local parks or forests and control of development therein by the State of Maine or other local interests is advocated.

Although none of the four projected reservoirs presents opportunity for economical combined simultaneous development for power and flood control, the Rumford Reservoir taken singly and the group consisting of Rumford, Dixfield and Buckfield, developed to provide only the requisite flood-storage capacity, but operated during other than peak-flood seasons to yield supplemental power benefits by retention of a fractional part of the available storage, appear to be economically justified at some future date when the local power system is able to absorb the energy thus generated. Under such a plan of operation, it is recommended that the distribution of costs between the power interests and the Federal and State Governments be in proportion to the respective benefits to flood control and power, the latter benefit accruing principally from the conversion of secondary to primary energy at existing and potential downstream plants.

War Department
United States Engineer Office
Boston, Massachusetts

December 30, 1936

Subject: Review Report on Androscoggin River, Maine and New Hampshire

To: The Division Engineer, North Atlantic Division, New York, N. Y.

INTRODUCTION

1. Authority. - This review report is submitted in accordance with the following Resolution of the Committee on Flood Control, United States House of Representatives, adopted and approved March 27, 1936:

"RESOLVED, By the Committee on Flood Control of the House of Representatives, United States. That the Board of Engineers for Rivers and Harbors, created under section 3 of the river and harbor act approved June 13, 1902, be; and is hereby requested to report to this Committee at the earliest practicable date, the results of the additional studies and investigations made on the Androscoggin River, to take into account important changes in economic factors, additional stream flow records, or factual data developed as a result of the recent severe flood, with a view to revising the report on this river printed as House Document No. 646, 71st Congress, 3d session;"

and the following Resolution of the Committee on Commerce, United States Senate, adopted March 28, 1936:

"RESOLVED BY THE COMMITTEE ON COMMERCE OF THE UNITED STATES SENATE, That the Board of Engineers for Rivers and Harbors created under Section 3 of the River and Harbor Act approved June 13, 1902, be and is hereby requested to review the report on Androscoggin River, Maine, submitted in House Document 646, 71st Congress, 3d Session, with a view to determining whether any modification of the recommendations contained therein is deemed advisable as a result of the recent severe floods;"

2. Necessity for Review of Previous Report. - The recommendations contained in the report under review (H. Doc. No. 646, 71st Congress, 3d Session) were unfavorable to further improvement of the river for navigation in connection with power development, the control of floods, the needs of irrigation or any combination thereof. Since this report was submitted, the severe floods of March, 1936, occurred, that of March 19, 1936, being of unprecedented magnitude in the Androscoggin River valley. These floods have indicated the necessity for further study and investigation of the problem of flood control in this basin.

3. Prior Reports. -

SCOPE OF REPORT	DATE	WHERE PUBLISHED	RECOMMENDATION
Survey - Brunswick Hbr. on the Androscoggin River	1881	Sen.Ex.Doc.No.45 47th Congress, 1st Session	Unfavorable
Preliminary Examination (Androscoggin River, below Brunswick, Maine)	1882	Sen.Ex.Doc.No.30, 48th Congress, 1st Session	Unfavorable
Preliminary Examination (Androscoggin River between Merrymeeting Bay and Lewiston-Auburn)	1917	H. Doc. No. 79, 65th Congress 1st Session	Unfavorable
Report under provisions of H. Doc. No.308,69th Congress, 1st Session. Navigation, flood control, power development and irrigation	1930	H. Doc. No. 646, 71st Congress, 3d Session	Unfavorable
Report on Navigable Status	1931	Not printed - Boston District File 1256/5 Misc.	Head of navigation, natural falls and dam at Brunswick, Maine

A list of reports by other agencies is given in APPENDIX A.

4. Maps. - The United States Geological Survey general maps of Maine and New Hampshire (scale 1:500,000, or about 8 miles to 1 inch), and Sheet 1 of the New Hampshire Transportation Map and Sheets 2 and 6 of the Maine Transportation Map (scale 1:250,000, or about 4 miles to 1 inch) issued by the Bureau of Public Roads, include the basin. The Geological Survey topographic sheets (scale 1:62,500, or about 1 mile to 1 inch) cover about 85 per cent of the area. Some details of the tidal portion of the river are shown on United States Coast and Geodetic Survey Charts Nos. 314 and 1204, but these contain no soundings above the outlet into Merrymeeting Bay. The United States Geological Survey has issued a profile of the main river from tidewater to Umbagog Lake (scale 1:24,000 horizontal and 20 feet to 1 inch vertical) with maps of the upper portion beginning at a point about

10 miles below Rumford, Maine. The survey for these maps and profile was made in 1905.

LOCATION AND DESCRIPTION

5. Drainage Basin. - The watershed of the Androscoggin River lies principally in western Maine, with part of the headwater area, comprising 20 per cent of the total, lying in New Hampshire (see Figures 1 and 2). The basin has a length of 110 miles, maximum width of 55 miles and a total area of 3,470 square miles. The lake and pond area of 143 square miles, 4.1 per cent of the total area, exercises complete or partial control over approximately 1400 square miles, or 40 per cent of the entire basin. The general elevation of the watershed is higher than that of any other eastern river in the United States. The upper portions are rough, mountainous and almost entirely covered by forests. The lower portions are hilly, partly wooded and contain considerable cultivated land.

6. The lower portion of the basin is characterized by broad, low hills and long, gentle slopes with prevalent large lake and swamp areas. The upper portion of the basin is dominated by irregular groups of steep hills and low mountains, with numerous lakes and marshes in the intervening lowlands. The lowlands and much of the hill topography constitute the haphazard, little dissected, surface of the deep glacial overburden beneath which the pre-glacial bedrock drainage courses are completely buried. Across the lowest areas of this overburden the Androscoggin River and its tributaries follow irregular winding courses in poorly-defined valleys. Development of tributary drainage is still rudimentary. While bedrock is exposed, or close to the surface, in the high hills and mountains, outcrops are small and scattered in the lowlands. Bedrock is exposed in numerous short channel reaches, but, with few exceptions, the channel has not been incised into the rock more than 5 to 10 feet. Bedrock within the drainage area is predominantly granite, schist and gneiss with occasional areas of slate and other metamorphic rocks. The

overburden consists mainly of gravelly, somewhat silty sands. Extensive deposits of sand and, in some areas, silt, are found in the lowlands.

7. The upper part of the basin is largely wild land with comparatively few settlements, almost all of which are on, or close to, the streams. In the lower half of the basin there is a large volume of manufacturing, the principal products being cotton goods, pulp and paper. This part of the basin, below Rumford, is served by the Maine Central and Grand Trunk Railroads and by good highways. In the upper half there is a branch of the Maine Central Railroad which follows the Swift River to serve the Rangeley Lake district and the Grand Trunk Railroad Line which roughly parallels the west limit of the basin to Berlin where it turns out of the watershed.

8. The only cities and towns in the basin with populations exceeding 3,000 are the following (all located on the main river):

PRINCIPAL CITIES AND TOWNS

City or Town	Population (1930 Census)	Distance from Tidewater (miles)
Lewiston, Me.	34,939	24
Auburn, Me.	18,571	24
Berlin, N. H.	20,018	134
Rumford, Me.	8,726	82
Brunswick, Me.	7,604	0
Lisbon, Me.	4,002	7

The total population of the basin in 1930 was nearly 150,000; approximately 124,000 in Maine and 26,000 in New Hampshire.

9. Main River. - The river rises at the Canadian border near the boundary between the States of Maine and New Hampshire in mountainous territory which lies at an elevation of 2600 to 2900 feet above mean sea level. The main river is considered as having its source in Umbagog Lake but the actual headwaters of the principal contributing streams lie about 40 miles further north. From Umbagog Lake the river flows in a southerly direction in New Hampshire for about 35

miles before turning east into Maine. From the Maine-New Hampshire line the river continues in an easterly direction for a distance of 70 miles and then turns to flow generally south for 60 miles before reaching tidewater at Brunswick, Maine. The mouth of the river is at its outlet into the west end of Merrymeeting Bay, a tidal basin through the eastern portion of which the Kennebec River flows. The total length of the Androscoggin River from headwater to tidewater is about 200 miles.

10. Umbagog Lake lies at an elevation of 1244 feet above mean sea level, so that the average slope of the river in the 167 miles from Umbagog Lake to tidewater is nearly 7.5 feet per mile. In the 30 miles from Umbagog Lake to a point just above Berlin, New Hampshire, there is a fall of 152 feet, or 5.1 feet per mile. In the next 2.7 miles there is concentrated a fall of 238 feet, or slightly more than 88 feet per mile. From this point to the state line, a distance of 35 miles, the fall is 174 feet, or 5.0 feet per mile. The fall from the state line to the mouth of the Swift River at Rumford, a distance of 37 miles, is 258 feet, or 7.0 feet per mile, but included in this reach is a fall of 177 feet in a distance of 1.7 miles at Rumford, more than 100 feet per mile. In the next 21 miles there is a fall of only 68 feet, or 3.2 feet to the mile, and in the remaining 61 miles to tidewater, 354 feet, or nearly 6 feet to the mile.

11. Records of discharge of the main river at Auburn, Maine (drainage area 3260 square miles), 24 miles above Brunswick, for the 9-year period 1928 - 1936 give: maximum 135,000 cubic feet per second (March 20, 1936); minimum 465 cubic feet per second; mean 5420 cubic feet per second. (These discharges are affected by storage regulation above.)

12. The tidal portion of the river extends from Merrymeeting Bay to the natural falls and dam at Brunswick, a distance of about 3 miles. The mean range of tide in this reach varies from 3 to 5 feet and the controlling depth at mean low water is 3 feet or less.

13. Tributaries. - The principal tributaries of the Androscoggin River in order of location from headwater to mouth are as follows:

TRIBUTARIES OF THE ANDROSCOGGIN RIVER

River	Drainage Area (sq. mi.)	Location: Headwaters	Location: Mouth	Distance of mouth from tidewater (miles)	Discharge of Record c.f.s./sq.mi.: Max.	Min.	Mean
Magalloway	500	At International boundary 13 Mil. W. of Big Island, Me.	Errol, N. H.	165		Completely regulated	
Swift	135	5 Mi. N. of Houghton, Me.	Rumford, Me.	82	136.84	.05*	1.87
Webb	125	3 Mi. N.E. of Weld, Me.	Dixfield, Me.	75		No gaging station	
Dead	100	4 Mi. N. of Vienna, Me.	5 Mi. No. of Leeds, Me.	46		No gaging station	
Nezinscot	275	2 Mi. N.W. of Redding, Me.	4 Mi. N.E. of Turner; Me.	38		No gaging station	
Little Androscoggin	380	Bryant Pond, Me.	Auburn, County,Me.	24	46.58	.01*	1.83

* Regulated by controlled storage.

HYDROLOGY OF THE BASIN

14. Climate. - The Androscoggin watershed lies in the path of the planetary winds known as the "prevailing westerlies", and in the path of the extratropical cyclones which traverse the United States in a generally west to east direction. The regularity of prevailing westerly winds in New England, is, however, greatly broken up by this cyclonic activity, so that only long averages show the prevailing westerly direction. The extratropical cyclones account for the characteristic succession of high and low barometric pressures, the "lows" being associated with unsettled weather and more or less precipitation. These storms approach New England in directions varying from west or somewhat north of west to south southwest. Those approaching from the more southerly directions travel

along the Atlantic coastline and, because of their more abundant supply of moisture, tend to result in greater precipitation. Extratropical cyclones cross over, or close enough to, New England to affect the Androscoggin watershed throughout the year. In addition to these storms, others of tropical origin, that is, West Indian hurricanes, also affect New England. These hurricanes, after leaving the regions of their origin, turn northward and move along the customary paths of extratropical cyclones, but lose, however, much of their original violence before reaching New England. These storms result in heavy precipitation but since their occurrence is limited to the seasons of late summer and early fall, when the watershed is in condition to absorb large quantities of water, the danger of serious floods from that source is greatly diminished.

15. The temperature of the region varies widely, from below freezing in winter to the high summer temperatures required to support an abundant and varied plant life. Some relief from extremes results from the proximity of the Atlantic Ocean, but this effect is counteracted somewhat by the offshore direction of the prevailing winds.

16. The foregoing conditions produce a climate of variable weather, characterized by frequent, but short, periods of heavy precipitation. This precipitation is rather uniformly distributed throughout the year, with a probability of torrential rains somewhat higher for the month of September, coinciding with the season of coastwise hurricanes from the tropics. A heavy annual snowfall results from the sustained low temperatures of winter.

17. <u>Records of Temperature and Precipitation.</u> - The United States Weather Bureau maintains nine observation stations for temperature and precipitation in the Androscoggin watershed. Records from these stations have been supplemented by records from three stations located in adjacent areas. All stations used in this study of the Androscoggin River are listed in the following table:

OBSERVATION STATIONS FOR PRECIPITATION AND TEMPERATURE

Station	Elevation (Feet above M.S.L.)	Period of Record	Length of Record (Years)	Remarks
		Stations in Androscoggin Watershed		
Oquossuc Dam, Me.	1534	1900-1930	31	1902,03,07,09, 12-16, 30 records incomplete
Upper Dam, Me.	1484	1886-1935	50	
Middle Dam, Me.	1430	1905-1935	31	1935 record incomplete
Aziscohos Dam, Me.	1528	1911-1933	23	1933 record incomplete
Errol, N. H.	1260	1885-1935	51	1929,30,32,34 records incomplete
Milan, N. H.	1190	1887-1898 1926-1935	22	1898,1926 records incomplete
Berlin, N. H.	1110	1887-1903 1918-1935	35	
Rumford, Me.	505	1894-1935	42	
Lewiston, Me.	182	1875-1935	61	
		Stations in Areas Adjacent to Androscoggin Watershed		
In Presumpscot River Basin				
North Bridgton, Me.	450	1893-1935	43	1893,1894 records incomplete
In Kennebec River Basin				
Farmington, Me.	425	1891-1935	45	
Gardiner, Me.	139	1837-1935	99	

18. Temperature. - The mean annual temperature as determined from the records of four stations (Berlin, Rumford, Lewiston and Farmington) is 42.7 degrees Fahrenheit. Mean monthly and annual temperatures at these stations are given in the following table and are shown, graphically in Figure 3.

MEAN MONTHLY AND ANNUAL TEMPERATURE - DEGREES FAHRENHEIT

Month	Berlin,N.H.	Rumford,Me.	Lewiston,Me.	Farmington,Me.	All Stations
Elev.	1110	505	182	425	
Jan.	13.5	16.7	18.2	15.6	16.0
Feb.	15.6	17.7	18.9	17.4	17.4
Mar.	27.5	29.1	29.8	28.9	28.8
Apr.	39.7	41.1	41.9	41.9	41.2
May	52.0	53.2	53.9	54.2	53.3
June	61.0	60.4	63.5	63.1	62.0
July	66.2	68.4	69.4	68.1	68.0
Aug.	63.2	65.2	66.8	65.6	65.2
Sept.	56.4	58.0	59.5	58.0	58.0
Oct.	45.9	47.3	48.8	47.2	47.3
Nov.	32.5	33.9	35.8	34.0	34.1
Dec.	18.8	21.8	23.3	21.3	21.3
Annual	41.0	42.7	44.2	42.9	42.7

19. Precipitation. - The mean annual precipitation as determined from the records of nine stations (Upper Dam, Middle Dam, Errol, Berlin, Rumford, Lewiston, North Bridgton, Farmington and Gardiner) is 39.4 inches. Mean monthly and annual precipitations at these stations are given in the following table and are shown, graphically, in Figure 4.

MEAN MONTHLY AND ANNUAL PRECIPITATION* IN INCHES

Month	Upper Dam	Middle Dam	Errol,N.H.	Berlin,N.H.	Rumford,Me.
Elev.	1484	1430	1260	1110	505
Jan.	2.44	2.05	2.78	2.95	2.88
Feb.	2.06	1.84	2.61	2.82	2.91
Mar.	2.55	2.18	2.82	3.33	3.32
Apr.	2.18	2.42	2.60	2.65	3.22
May	2.93	3.33	2.97	2.91	3.28
June	3.26	3.56	3.79	3.63	3.53
July	3.25	3.61	3.78	3.50	3.67
Aug.	3.28	3.96	3.95	3.61	3.58
Sept.	3.15	3.52	3.43	3.10	3.50
Oct.	2.51	3.01	3.10	3.04	3.19
Nov.	2.78	2.85	3.11	3.44	3.36
Dec.	2.38	2.11	2.82	2.98	2.90
Annual	32.77	34.44	37.76	37.96	39.34

* Including water equivalent of snow precipitation.

MEAN MONTHLY AND ANNUAL PRECIPITATION IN INCHES (Cont'd)

Month	Lewiston, Me.	N.Bridgton, Me.	Farmington, Me.	Gardiner, Me.	All Stations
Elev.	182	450	425	139	
Jan.	3.84	3.46	3.29	3.59	3.03
Feb.	3.73	3.34	2.95	3.44	2.86
Mar.	4.28	3.91	3.90	3.91	3.35
Apr.	3.42	3.45	3.29	3.33	2.95
May	3.47	3.55	3.68	3.64	3.31
June	3.48	3.58	3.68	3.23	3.53
July	3.60	4.19	3.45	3.37	3.60
Aug.	3.21	3.64	3.87	3.51	3.64
Sept.	3.52	3.70	3.59	3.33	3.43
Oct.	3.59	3.21	3.44	4.08	3.24
Nov.	3.83	3.61	3.59	3.93	3.39
Dec.	3.91	3.44	3.46	3.64	3.07
Annual	43.88	43.08	42.19	43.00	39.40

20. Distribution of Precipitation. - Figure 5 is a general isohyetal map showing the distribution of annual rainfall throughout New England. The monthly frequency of heavy rains (those having 24-hour precipitation in excess of 2 inches) at Rumford, Me., is shown in Figure 6.

21. Expected Rainfall. - The expected frequency of heavy rainfall has been computed for two stations on the watershed: Rumford, Maine, and Berlin, New Hampshire (the latter combined with Bethlehem, New Hampshire). The amount of rainfall which may be expected in one day is as follows (see Figures 7 and 8):

EXPECTED FREQUENCY OF RAINFALL

Period	Rumford, Me.	Berlin-Bethlehem, N. H.
Once in 1 year	2.0 inches or more	1.7 inches or more
" " 10 years	3.8 " " "	3.2 " " "
" " 25 "	4.8 " " "	4.1 " " "
" " 50 "	5.5 " " "	4.8 " " "
" " 75 "	5.9 " " "	5.2 " " "
" "100 "	6.3 " " "	5.6 " " "

22. Showfall. - Figure 9 is a general isohyetal map of snowfall in New England. Snowfall on the Androscoggin watershed varies from 77 inches

on the coast to 130 inches on the northern headwaters.

23. <u>Snow Surveys</u>. - For a number of years the power companies operating on the Androscoggin River have conducted through the winter snow surveys in the Rangeley Lakes region. By means of these surveys the companies obtain data regarding the "snow cover", that is the depth of snow on the ground and its water equivalent. These data are utilized in operating the storage reservoirs which are filled each spring by run-off from the accumulated snow and incidental rainfall. For the past two years these snow surveys have been complete enough to show the gradual accumulation of the snow blanket throughout the winter (see Figures 10 and 11). Data from these snow surveys show the depletion of the snow cover during March, 1936. This is illustrated in Figure 12.

24. An additional study was made of the snow run-off from that portion of the watershed between Errol, New Hampshire, and Rumford, Maine. This study included the months of March, April and May for the period from 1925 to 1936. The run-off from rainfall was computed by means of a distribution factor and the unit hydrograph (see Paragraph 81) on the assumption that all of the rainfall on top of the snow became run-off. The excess of observed run-off over that computed was attributed to melting snow. Snow run-off should, therefore, be equal to or greater than that shown. The daily melt of snow was then computed by reversing the application of the distribution factors. These quantities are shown in Figures 13 to 16. An explanation of the methods of computation is contained in the review (now being prepared) of the report on the Merrimack River, New Hampshire and Massachusetts, submitted in 1929 and printed in H. Doc. No. 649, 71st Congress, 1st Session. This review report is hereinafter referred to as the "1936 flood control report on the Merrimack River".

25. <u>Stream-Flow Records</u>. - The United States Geological Survey has maintained eleven gaging stations in the basin (see Figure 2). Statistics of these stations are given in the following table:

STREAM GAGING STATIONS

Location of Gaging Station	Drainage Area	Period of Record	Discharge Cubic Feet Per Second Mean	Maximum	Minimum
	(sq. mi.)			**	
Androscoggin River					
Errol, N. H.	1090	1905-1923	Completely Regulated		
Berlin, N. H.	1380	1913-1922	2180	14,300	*
Gorham, N. H.	1390	1929-1936	2360	19,900	960*
Shelburne, N. H.	1500	1903-1907	--	15,600	*
Rumford, Me.	2090	1892-1936	3480	74,000	*
Dixfield, Me.	2230	1902-1908	4940	--	*
Gulf Island, Me.	2860	1936	--	118,000	1550*
Auburn, Me.	3260	1928-1936	5420	135,000	465*
Magalloway River					
Aziscohos Dam, N. H.	233	1912-1935	Completely Regulated		
Swift River					
Roxbury, Me.	95	1929-1936	178	13,000	5
Little Androscoggin River					
South Paris, Me.	76	1913-1924 1931-1936	139	6,980	1

* Flow regulated by controlled storage
** Instantaneous peak discharges

Information concerning the accuracy of records from the above-listed gaging stations is given in APPENDIX C.

26. Mean Monthly Flow. - The mean monthly flow of the Androscoggin River at Rumford, Maine, with the equivalent run-off, is given in the following table. The mean monthly run-off is also shown graphically in Figure 17.

MEAN MONTHLY FLOW AT RUMFORD, MAINE
(Drainage Area 2090 square miles)

Month	Discharge: Cubic Feet Per Second	Discharge: Cubic Feet Per Second Per Square Mile	Equivalent Run-off in Inches
January	2460	1.18	1.36
February	2320	1.11	1.16
March	3760	1.80	2.07
April	7260	3.47	3.88
May	6830	3.27	3.77
June	3920	1.88	2.09
July	2510	1.20	1.38
August	2240	1.07	1.24
September	2310	1.10	1.23
October	2550	1.22	1.41
November	3090	1.48	1.65
December	2500	1.22	1.41
Annual	Mean 3480	Mean 1.67	Total 22.65

NAVIGATION

27. Portion Improved. - No improvement of the Androscoggin River in the interests of navigation has ever been undertaken by the United States.

28. Latest Survey. - The only survey by the United States of the tidal portion of the river was made in 1881 for the report published in Sen. Ex. Doc. No. 45, 47th Congress, 1st Session. This survey showed a controlling depth of 3 feet at mean low water to Brunswick, Maine.

29. Latest Mention in Annual Report of the Chief of Engineers. - The latest mention of the Androscoggin River in Annual Report of the Chief of Engineers was in Part 1, page 68, of the report for 1917.

30. Present Depth. - Present depths in the tidal portion of the river are not known, no soundings being shown on the United States Coast and Geodetic Survey Chart No. 1204 above the outlet into Merrymeeting Bay. It is probable, however, that the controlling depth to Brunswick is not greater than the 3 feet at mean low water indicated by the survey of 1881.

31. Commerce. - No commercial statistics are available.

32. Discussion. - Prior reports (see Paragraph 3) have been unfavorable to improvement of this river in the interests of navigation. The conclusions of the report under review (H. Doc. No. 646, 71st Congress, 3d Session) were that any extension of navigation through or above tidewater would not be economically advisable. New developments which would require revision of these conclusions have not taken place. There is no reason, nor demand, for improving the tidal portion of the river below Brunswick. The population of Brunswick, a manufacturing town at the head of tidewater, is about 7,600; of Lisbon, the next upstream, about 4,000; and of Lewiston, the largest city in the basin, nearly 55,000, including Auburn which lies across the river. Navigation could be extended above Brunswick only at high cost by means of locks with dams where necessary. To reach Lewiston and Auburn a rise of 113 feet would have to be overcome in 24 miles and, while some of the existing dams might be used for slack water, locks would, in most cases, have to be cut into them, seriously reducing the spillway capacity.

Much rock excavation would be needed for the approaches, and it would be difficult to build any new structures without interfering with the mills. Above Lewiston and Auburn there are no towns of commerce sufficient to be benefited by navigation, and the tributary districts are largely undeveloped. Transportation by railroad and highway is adequate for present needs.

33. Conclusions. - No revision is required at the present time of the conclusions of H. Doc. No. 646, 71st Congress, 3d Session, that extension of navigation through or above tidewater would not be economically advisable.

IRRIGATION

34. The cultivated areas in the valley are small and the rainfall varies from 44 inches near the coast to 33 inches in the northern portion of the basin. This rainfall is ample for existing and prospective agriculture, and irrigation is unnecessary.

POWER DEVELOPMENT

35. General Discussion of Existing Power Development. - The Androscoggin River is highly developed for power generation. With a total drainage area in Maine and New Hampshire equal to 10.5 per cent of the area of the State of Maine, the installed generating capacity is 45 per cent of the total for the entire state. There are within the basin 53 water-power developments of more than 100 horsepower with a total installed generating capacity of nearly 248,000 horsepower.

36. The growth of power development in the Androscoggin basin during the past 25 years is shown by the following table, which is made up from the report under review (H. Doc. No. 646, 71st Congress, 3d Session), and from data furnished directly by the District Engineer of the Water Resources Branch of the United States Geological Survey at Augusta, Maine, and at Boston, Massachusetts.

Date	Installed Generating Capacity, horsepower In New Hampshire	In Maine	Total	Average Annual Increase (horsepower)
1910	22,100	101,355	123,455	
				6632
1928	55,050	187,781	242,831	
				732
1935	60,850	187,107	247,957	

37. The annual rate of increase was greatly retarded during the past seven years. This retardation was caused partially by the economic depression, partly by drift of the textile industry to the south, and largely by the completion, in 1932, of the Wyman power development on the Kennebec River, with an installed capacity of 68,000 horsepower. The absorption of this large volume of additional power was facilitated by the power transmission net interconnecting the various river basins (Figure 18). The same facility of distribution, however, exercises a retarding influence upon development in adjacent drainage areas pending absorption of adjoining surpluses of power.

38. Tabulation of Existing Developments. - The following table, taken from records of the United States Geological Survey, shows the installed horsepower, in plants of 100 horsepower and greater, in the Androscoggin basin, as existing in the year 1935:

POWER INSTALLATIONS IN THE ANDROSCOGGIN RIVER BASIN - 1935

(Installations of less than 100 horsepower not tabulated)

NAME OF DAM	LOCATION	OWNER	USE	HEAD (feet)	ACCUMULATIVE TOTAL HEAD (feet)	INSTALLED CAPACITY (horsepower)
MAIN RIVER IN MAINE						
Brunswick	Brunswick	Central Me. Power Co.	Pub. Util.	14)	14	1,932
Brunswick	Brunswick	Cabot Mfg. Co.	Mfg.	14)		500
Cabot Mfg. Co.	Brunswick	Cabot Mfg. Co.	Mfg.	19)	33	4,200
Cabot Mfg. Co.	Brunswick	Cabot Mfg. Co.	Mfg.	19)		6,000
Pejepscot Mills	Brunswick	Pejepscot Paper Co.	Paper	22	55	8,084
Lisbon Falls Lower	Lisbon Falls	Pejepscot Paper Co.	Paper	13.5	68.5	1,489
Lisbon Falls Upper	Lisbon Falls	Worumbo Mfg. Co.	Woolens	19	87.5	900
Union Water Power Co.	Lewiston	Union Water Power Co. with various lessees	Textiles & Pub. Util.	50 (max.)	137.5	23,666
Androscoggin No. 3)	Auburn	Central Me. Power Co.	Pub. Util.	31)	169.5	10,650
Deer Rips)	Lewiston	Central Me. Power Co.	Pub. Util.	32)		5,500
Gulf Island	Gulf Island	Central Me. Power Co.	Pub. Util.	50	219.5	27,000
Livermore Falls	Livermore Falls	Int. Paper Co.	Paper & Pulp	31	250.5	10,800
Otis	Chisholm	Int. Paper Co.	Paper & Pulp	24	274.5	9,426
Jay	Jay	Int. Paper Co.	Paper & Pulp	13.8	288.3	3,500
Riley	Riley	Int. Paper Co.	Paper & Pulp	20	308.3	6,963
Rumford (3d fall)	Rumford	Oxford Paper Co.	Paper	30	338.3	4,669
Rumford Falls Power Co. Middle	Rumford	Int. Paper Co.	Paper & Pulp	48	386.3	14,744
Rumford Falls Power Co. Upper	Rumford	Oxford Paper Co.	Paper & Pub. Util.	98	484.3	39,000
Total developed on main river in Maine				484.3		179,023

POWER INSTALLATIONS IN THE ANDROSCOGGIN RIVER BASIN - 1935

(Installations of less than 100 horsepower not tabulated)

NAME OF DAM	LOCATION	OWNER	USE	HEAD (feet)	ACCUMULATIVE TOTAL HEAD (feet)	INSTALLED CAPACITY (horsepower)
<u>MAIN RIVER IN NEW HAMPSHIRE</u>						
Lead Mine Bridge	Shelburne	Brown Co.	Mfg.	16	500.3	3,000
Shelburne	Shelburne	Brown Co.	Paper	17	517.3	4,900
Twin State Gas & Elec. Co.	Gorham	Twin State Gas & Elec. Co.	Pub. Util.	18	535.3	2,700
Gorham	Gorham	Brown Co.	Paper	30	565.3	6,000
Cascade Mill	Berlin	Brown Co.	Paper & Pub. Util.	44	609.3	10,800
Cross Plant	Berlin	Brown Co.	Paper	21	630.3	4,750
Glen Mill No. 5	Berlin	Int. Paper Co.	Paper & Pulp	22	652.3	4,000
Glen Mill B	Berlin	Int. Paper Co.	Pulp	21	673.3	4,600
Glen Mill C	Berlin	Int. Paper Co.	Pulp	37	710.3	5,100
Riverside	Berlin	Brown Co.	Mfg.	65	775.3	15,000
Total developed on main river in New Hampshire				291		60,850

POWER INSTALLATIONS IN THE ANDROSCOGGIN RIVER BASIN - 1935

(Installations of less than 100 horsepower not tabulated)

NAME OF DAM	STREAM	LOCATION	OWNER	USE	HEAD (feet)	INSTALLED CAPACITY (horsepower)
TRIBUTARIES IN MAINE						
Grants	Kennebago R.	Grants	Oquossoc Lt. & Power Co.	Pub. Util.	32	410
Barker Mills Lower	Little Andros. R.	Auburn	Central Me. Power Co.	Pub. Util.	38	800
Barker Mills Upper	Little Andros. R.	Auburn	Central Me. Power Co.	Pub. Util.	32	758
Littlefields	Little Andros. R.	Auburn	Central Me. Power Co.	Pub. Util.	23	1,488
Minot *	Little Andros. R.	Minot	Rogers Fibre Co.	Mfg.	11	224
Hackett Mills	Little Andros. R.	Hackett Mills	Rogers Fibre Co.	Mfg.	11	364
Mechanic Falls	Little Andros. R.	Mechanic Falls	Waterfalls Paper Mills	Paper	36	1,907
Oxford	Thomp[illegible] Stream	Oxford	Robinson Mfg. Co.	Textiles	11	315
Norway	Pennesseewassee L.	Norway	Central Me. Power Co.	Pub. Util.	52	450
Lisbon Centre	Sabattus R.	Lisbon Centre	Farnsworth Co.	Textiles	18	235
Lisbon	Sabattus R.	Lisbon	Lisbon Spinning Co.	Textiles	21	500
Sabattus	Sabattus R.	Sabattus	Park Mills Co.	Textiles	4	133
Turner	Nezinscot R.	Turner	Central Me. Power Co.	Pub. Util.	14	180
Chase Corners	Martin Stream	Chase Corners	Luther M. Hodsdon	Saw Mill	11	200
Hale	Swift R.	Hale	J. A. Thurston Co.	Saw Mill	19	120
Total developed on tributaries in Maine					333	8,084
Total developed in basin					1108.3	247,957

* Destroyed by March 1936 flood.

39. The Androscoggin has a smaller drainage area than either the Kennebec or the Penobscot, yet notwithstanding that no additions were made during the last seven years, the installed generating capacity is greater in the Androscoggin basin than in either of these other rivers. The power possibilities of the river are favored by the large upstream lake areas, which amount to approximately 80 square miles. Total storage in the basin amounts to 738,000* acre-feet, equal to 213 acre-feet per square mile. Characteristics of flow of the river are shown by the duration curves (Figures 19 and 20).

40. The principal producers of power for public utilities are the Central Maine Power Company and its subsidiary, the Androscoggin Electric Company. The systems of these companies are widely distributed and well interconnected for the interchange of electric power. Generating capacities at their plants, however, are considerably in excess of present requirements.

41. Power Market. - The growth of power development prior to 1930 was remarkable. At present power is developed on this basin at the rate of 54 horsepower per square mile of drainage area, as compared with 27 horsepower for the Kennebec and 15 horsepower for the Penobscot. Moreover, the normal flow in the river, with its great reserves of storage upstream, can produce much more power than now required. Most of the plants have the equipment and water available to furnish a large additional amount of electric power at little increase in operating costs. If this surplus power could be sold, it would materially reduce the unit cost of production.

42. The average yearly consumption and prices per customer of the Androscoggin Electric Company are shown in the following table:

AVERAGE ANNUAL ENERGY CONSUMPTION PER CUSTOMER

Year	Domestic Use		Industrial Use	
	Amount (Kilowatt-Hours)	Average Price (Cents per Kilowatt-Hour)	Amount (Kilowatt-Hours)	Average Price (Cents per Kilowatt-Hour)
1929	613	6.29	38,200	2.05
1931	811	5.29	34,500	1.87
1934	792	5.20	40,500	1.69

* From report of Maine State Planning Board, 1934-1935.

The average revenue from all electric energy sold by the public utilities in the basin for the year 1933 was 2.6 cents per kilowatt-hour.

43. An appreciable amount of the power used in the Androscoggin drainage area originates in the Kennebec watershed. The actual quantity so imported cannot be determined, however, since the principal utility, the Androscoggin Electric Company, is a subsidiary of the Central Maine Power Company, which operates principally in the Kennebec basin, and published production figures do not differentiate between their respective outputs. It is believed, however, that this interchange is of a fluctuating character, facilitated by the interconnecting transmission net and dependent upon variations in the demand (Figure 21).

44. This tendency towards a pooling of generating capacity **is** a desirable development, for a combined system can maintain a higher load factor and operate more economically, making it possible to reduce the cost to the consumer (Figure 22).

45. <u>Estimated Future Growth</u>. - At present the area is well supplied with power and there exists a considerable surplus generating capacity in existing plants. Further power development is limited by the distance to markets and by the Maine statute prohibiting the export of hydro-electric power from the state. The latter eliminates the metropolitan area of Boston as a possible market (Figure 23).

46. Future expansion of the power demand, therefore, barring legislative action by the state, is dependent upon the following factors:

- <u>a</u>. Increased industrial activity.
- <u>b</u>. Further farm electrification.
- <u>c</u>. Growth of population.

47. Undoubtedly the industries in the Androscoggin valley are due to participate in the recovery from the economic depression. This tendency, however, is offset by the emigration of the textile industry to the South. If this trend continues, it may about balance the normal growth of the pulp and paper mills. It is probable, therefore, that for the immediate future no large increase in market for industrial power

will occur.

48. The use of electricity on farms may provide an outlet for some of the surplus generating capacity, especially as a result of Federal aid for rural electrification. This development is already well advanced, however, since in 1934 approximately 33 per cent of the farms in the valley received electric service. In Androscoggin County this proportion was 47 per cent. A factor limiting further expansion is the continued decrease in farm utilization in the State of Maine, which decline amounted to 14.5 per cent between 1920 and 1930. Extension of service to a larger number of farms, while desirable, is handicapped by the wide scattering of farm houses and by the poor economic condition of the farmer. The most promising field for further rural consumption of power appears to lie in additional use of energy for household appliances and farm machinery on farms already connected. Between 1929 and 1934 electric consumption on farms in the area served by the Central Maine Power Company increased from 370 kilowatt-hours per customer to 500 kilowatt-hours, a gain of 34 per cent.

49. The best outlook for increased power consumption is undoubtedly in the field of domestic use. With expanding industrial recovery, and normal growth of population, it is to be expected that the number of customers will increase, also that a greater consumption per customer will result. During the business depression the electric manufacturing companies, unable to sell their heavy equipment, pushed the sale of household appliances to an extent unknown even in the prosperous days before 1930. It is believed that this use of appliances is largely responsible for the present record consumption of electric energy, at a time when the industrial load is still well below its former peak.

50. The following table illustrates the gain in electric consumption per customer between 1929 and 1934, in the area served by the Central Maine Power Company and its subsidiary, the Androscoggin Electric Company, as compared with the gain in the entire United States:

Class	Quantities 1929	1934	Per cent of Increase
Farm Consumption, per Customer Kilowatt-hours	370*	500	34
Total Number of Customers	51,894	57,663	11
Average Consumption, all Customers, Kilowatt-hours	445	690	55
United States as a Whole, Average per Customer, Kilowatt-hours	510*	631	24

*Approximately.

51. In spite of the favorable prospects for domestic power consumption the probable expansion is not likely to affect the present installed generating capacity of existing plants. There is still a large surplus to be absorbed, with a highly developed transmission system to facilitate the transfer of power. It is probable that there will still be a surplus available from outside sources after the generating capacity of the Androscoggin has been overtaken by the demand.

52. Reconstruction and modernization of older and smaller plants and possibly the installation of Kaplan type turbines in some of the latter would result in an increased output and efficiency. This will probably be the first step towards satisfying the rising demand in this district. It is not likely, however, that new developments will become necessary in the near future.

53. Potential Power Development. - The report under review (H. Doc. No. 646, 71st Congress, 3d Session) lists 39 potential power sites with undeveloped power possibilities in excess of 100 horsepower at each site. Of these 26 were on the main river and 13 on the tributaries. After eliminating locations at existing mills and on the tributaries where the possible developments would be too small or too far from markets to compete with power supplied by the public utility companies, there remained 16 sites on the main river, capable of developing 52,000 horsepower for 90 per cent of the time. These potential sites ranged in size from 1400 to 6000 horsepower. The average was 5200 horsepower.

54. Since the date of the above report, July 12, 1929, none of these sites has been developed. One reason for this is that the most favorable locations are already in use; another is the surplus generating capacity in the Androscoggin basin; a third is the ease and economy of importing power from the adjoining Kennebec basin. Redevelopment of old plants to produce more power will probably be carried out extensively before resorting to new construction for providing additional power.

55. In this connection, it is reported that at a number of the smaller plants, where turbines or other water wheels had been in use as prime movers of the mill machinery, the tendency has been to abandon such a drive in favor of electric motors. In these cases it is customary to discard entirely the local power plant and to purchase energy from the public utility companies, rather than to incur the higher costs of generating it at the mill site.

56. Combined Power and Flood-Control Benefits. - In connection with the study of flood control in the Androscoggin valley, four storage reservoirs are projected, at Rumford, Dixfield, Buckfield and Oxford. These sites have been studied with reference to their possibilities for power storage in combination with flood-control storage. The method of combination employed was to provide power storage in the lower portion of the reservoir and flood-control storage as a surchage on the power reservoir. In accordance with Departmental policy (NAD 73/83.1 August 17, 1936), the cost of the power storage (including the additional clearing required for the power portion of the reservoir*) was first determined by deducting from the estimated cost of a combined reservoir, the cost of providing the required flood-control storage alone in a smaller reservoir. However, in the present instance, since, as shown by the tabulation given subsequently in Paragraph 104, the benefits to power are nearly equal to, or greater than, the benefits to flood control, it is believed that the allocation of costs to the power interests and the Federal and State Governments should be in proportion to the respective benefits to power and flood control.

57. The cost of a hydro-electric development at the reservoir site

* For flood-control storage alone, only dead wood has to be cleared from the timbered area within the reservoir site, but for power storage complete clearance is required.

was determined from the estimated unit cost of $60 per installed kilowatt of capacity, made up as follows:

a.	Power house	$20
b.	Water wheel, governor, generator and accessories	22
c.	Station service - Machine shop	1
d.	Switch gear and wiring	4
e.	Tailrace	3
f.	Intake and penstocks	10
	Total	$60

Annual charges were estimated as follows:

	Power House and Equipment	Dam and Reservoir (Power Portion)
Interest on investment	5%	5.0%
Amortization	2%	0.5%
Maintenance and operation	3%	1.0%
Taxes and insurance	2%	0.5%
Total	12%	7.0%

Plant efficiency, water to switchboard, was estimated at 80 per cent. It was assumed, for the purpose of this investigation, that evaporation from the reservoir surface will equal the precipitation upon it. The water utilization factor was estimated at 0.80.

58. The study of power possibilities in combination with flood-control storage showed that the economic factors were favorable to a combined development only at the Rumford site, located on the main river about 85 miles above tidewater. The principal physical features and elements of cost are shown in the table following Paragraph 61.

59. The storage allotted to power in the combined development would provide a continuous flow at the reservoir site of 2,340 cubic feet per second. Utilizing this flow, about 46,000,000 kilowatt-hours of primary energy could be generated annually at a power plant at the site. Operation of the Rumford Reservoir for maximum primary energy at the site would produce an increase in the annual output of the downstream plants equal to 37,000,000 kilowatt-hours of primary energy. The average unit

cost of 83,000,000 kilowatt-hours of energy produced annually at the reservoir site and downstream would be 4.9 mils. If consideration be given to potential sites, now undeveloped, the total output becomes 96,000,000 kilowatt-hours annually, at a unit cost of 4.3 mils. Of the developed head of 484 feet below the site, it is estimated that installations utilizing a total head of 407 feet have sufficient capacity to benefit from increased low flow. Accordingly, the increase in energy at existing downstream plants is based on a total head of 407 feet, the increase at potential downstream plants on a total head of 148 feet (undeveloped head below site plus developed head at installations not of sufficient capacity to benefit from increased low flow).

60. If no power development be provided at the reservoir, and the power storage be used exclusively for increasing the low-water flow of the stream, the reservoir may be operated so as to obtain the maximum increase in output of power plants downstream. Under these conditions it is estimated that the existing downstream plants would be enabled to produce an additional 79,000,000 kilowatt-hours of primary energy at a unit cost of 3.9 mils. If potential sites be included, the total annual output would become 108,000,000 kilowatt-hours, at a unit cost of 2.9 mils.

61. The foregoing data are summarized in the following table. Because of the great preponderance in the State of Maine of hydro over steam power, and of the statute prohibiting the export of hydro-electric energy from the state, secondary power lacks a ready market and is consequently of no value. Accordingly, only the increased primary energy from the combined development was included in the computations. The tabulated costs of primary energy have been determined as outlined in Paragraph 57, in accordance with the departmental policy (NAD 73/83.1 August 17, 1936) relative to the combined use of reservoirs for both flood-control and power purposes, which provides that the additional cost of obtaining power benefits will be contributed by the power beneficiaries. The low unit costs tabulated could not be realized unless nearly 70 per cent of the cost of the reservoir were charged to flood control.

POTENTIAL DEVELOPMENT FOR COMBINED STORAGE

FOR POWER AND FLOOD CONTROL

Rumford Reservoir

Drainage area	2,090	square miles
Spillway elevation proposed for flood storage alone	655	feet. U.S.G.S. datum
Flood-control storage	295,000	acre-feet
Spillway elevation proposed for combined development	670	feet. U.S.G.S. datum
Maximum water-surface elevation for power storage	655.5	feet. U.S.G.S. datum
Power storage	297,500	acre-feet
Tailwater elevation	610	feet. U.S.G.S. datum
Maximum gross head	45.5	feet
Average net head	33.2	feet
Prime flow	2,340	cubic feet per second
Installed capacity at the site*	10,500	kilowatts
Developed head below the site	484	feet
Potential undeveloped head below the site	71	feet

<u>Costs</u> (including interest during construction)

Combined storage for flood control and power	$16,063,000
Flood-control storage	11,664,000
Power storage	$ 4,399,000
Power house and equipment, development at the site	850,000
Total cost of power development at site	$ 5,249,000

<u>Annual Charges for Power Development</u>

Reservoir and dam	$ 308,000
Power house and equipment	102,000
Total	$ 410,000

* Assumed capacity factor, 0.50.

POTENTIAL DEVELOPMENT FOR COMBINED STORAGE - POWER AND FLOOD CONTROL (Continued)

RUMFORD RESERVOIR

Analysis of Power Costs -

Method of Operation *	Cost Allocation		Annual Charges for Power Development	Annual Primary Energy Output in Kilowatt-Hours				Average Cost of Primary Energy at Switchboard (Mils per Kilowatt-hours)
	Flood Control **	Power **		At Site	Increase at Existing Downstream Plants	Increase at Potential Downstream Plants	Total	
1(a)	$11,664,000	$5,249,000	$410,000	46,000,000	37,000,000	-	83,000,000	4.9
1(b)	11,664,000	5,249,000	410,000	46,000,000	37,000,000	13,000,000	96,000,000	4.3
2(a)	11,664,000	4,399,000	308,000	-	79,000,000	-	79,000,000	3.9
2(b)	11,664,000	4,399,000	308,000	-	79,000,000	29,000,000	108,000,000	2.9

*Methods of Operation

1. For maximum primary energy from power development at site.
   (a) Benefits to existing, but not potential, downstream power developments included.
   (b) Benefits to existing and potential downstream power developments included.
2. For maximum primary energy from existing downstream plants. No power installation at site.
   (a) Benefits to potential downstream power developments not included.
   (b) Benefits to potential downstream power developments included.

** Including interest during construction.

62. The average cost of generation in this area is about 5 mils* per kilowatt-hour. The costs shown in the table following Paragraph 61 indicate that if the Rumford Reservoir is to be built for flood-control storage, a combined development for flood control and power might be preferable to one for flood-control storage alone. Further economic analysis is necessary to determine whether the combined development is justified. The results of this study are shown in Paragraph 104.

63. Discussion. - The Androscoggin River is an important power stream. Development has been favored by the steep slope of the river, by the large storage afforded, particularly at the headwaters, and by the ready market for power in the mills, principally textile, pulp and paper making, which have grown up along the river. The installed generating capacity expanded very rapidly up to about 1930, but the rate of increase has since fallen off, partly because of the economic depression, partly on account of a migration of the textile industry to the South, but largely because of the low cost of imported power and the ease with which it can be transmitted from the adjacent Kennebec basin. A large excess generating capacity now exists in both the Androscoggin and Kennebec drainage areas, and a considerable addition to this capacity is feasible by redeveloping and modernizing old plants. Resumption of the former rate of expansion is not likely in the immediate future.

64. Investigation of the possibilities of developing combined storage for power and flood control at the Rumford, Dixfield, Buckfield and Oxford flood-control reservoir sites indicated that economic factors were favorable to a combined development only at the Rumford site. The average cost of power generation by the leading utility companies in this section, including interest charges, is about 5 mils per kilowatt-hour. With operation of the Rumford combined development to provide maximum primary energy from power development at the site, the average cost of the energy generated at the site and the increased energy output from existing downstream plants would be 4.9 mils per kilowatt-hour. If all the potential downstream sites were developed, this cost would be reduced to 4.3 mils per kilowatt-hour.

* The report "Water Power Resources", State of Maine, 1929, gave the cost of generation including interest charges, for the three largest public utility companies of the State (Central Maine Power Co., Cumberland County Power and Light Co., and Bangor Hydro-Electric Co.) as 5.0 to 5.9 mils per kilowatt-hour. Since 1929, these costs have decreased and are now about 4.5 to 5.3 mils per kilowatt-hour.

The same study, however, shows that even lower costs may be realized by omitting the plant at the reservoir site and operating the storage to increase the primary output of the downstream plants. Assuming that a market could be found for the increased output and that the financial cooperation of the downstream power companies would be forthcoming to permit the combined development, there should result from the low cost of the additional power a substantial annual return to apply on the annual charges of the flood-control storage.

65. The computed costs, however, are possible only by charging nearly 70 per cent of the reservoir cost to flood-control storage, in accordance with the allocation described in paragraph 56. It remains to be determined, therefore, whether the amount charged to flood control will be justified by the resulting flood benefits. In other words, the above power benefits are dependent upon an economic study of the combined development, considering both power and flood benefits. This study is summarized in paragraph 104 of the section of flood control.

66. Conclusions. - The report under review (H. Doc. No. 646, 71st Congress, 3d Session), states under "Conclusions", paragraph 30 * * * "additional general development of the Androscoggin is not economically advisable at the present time, due to the limited demand for power, and to the fact that the Kennebec River possesses undeveloped sites of superior economic promise" * * * It is not believed that present conditions warrant a change in these conclusions. Studies of the four project flood-control reservoirs to determine possibilities of combined storage for power and flood control indicate such possibilities at only one of these sites -- Rumford on the main river. The success of such a development, however, depends upon the realization of flood benefits sufficient to carry a large portion of the reservoir cost. The Androscoggin River, in spite of the present power situation, has a number of features favorable to power production, its potential generating capacity is large, and the consumption of power is increasing. Therefore, any conclusions placing a limitation on power production in the Androscoggin valley must be confined to the near future.

FLOOD CONTROL

67. General. - In the Androscoggin River basin, damage from the floods of March, 1936, the highest of record, extended principally from Rumford, Maine, to the mouth. Above Rumford there is no extensive development, except at Berlin, New Hampshire, and regulation by the Rangeley Lake storage system reduced flood stages to such a degree that only minor damage occurred at Berlin, and that largely from a local stream. Below Rumford, the valley being well developed agriculturally and industrially, heavy losses were suffered. Principal losses were at Rumford, Lewiston, Auburn, and Brunswick. Extensive damage to highways, railways and bridges also occurred in this portion of the basin.

68. Causes of Floods. - The two principal causes of floods on the Androscoggin River are heavy rainfall and rapid melting of deep snow cover. They may occur either singly or together. The principal type of storm is the extratropical cyclone. These storms frequently pass over the watershed at varying intervals of time, usually accompanied by precipitation in variable quantities. They occur throughout the year and may bring heavy rainfall in spring when a deep snow cover exists. Tropical cyclones, or hurricanes, may also reach the watershed and bring intense rainfall. These storms, however, occur only in the summer and early fall, at a time when the ground conditions are usually such that much of the heavy rainfall can be absorbed without causing large floods. On the other hand, if such storms should occur over a saturated watershed, flood conditions may develop. Furthermore, the watershed is subject to shifting air masses from both the polar and tropical regions. These shifting air masses are usually marked by "lows" on the edges. They may occur at any season in the year, and in the event of a warm tropical air mass arriving in early spring, a disastrous flood

is likely to result. A more complete discussion of the types of storms over New England and a study of 72 actual storms which occurred from 1906 to 1936 are contained in the 1936 flood control report on the Merrimack River.

69. As indicated above, snow has an important effect upon stream flow in this basin. A deep snow cover is actually stored precipitation, which may be released and appear in the streams as run-off with little warning, as a result of heavy rain or a sudden thaw. It is usually a contributing cause of floods in the spring and it may be the main cause. Studies were made of snow run-off from the Androscoggin River basin between Errol and Berlin, New Hampshire, which show that its characteristics are similar to those of run-off from rainfall. The snow melt, or computed depth of water per day resulting from melting snow, has been determined, for this portion of the basin, for the years 1925 - 1935, and is shown in Figures 13 - 16. As the snow is melted, either with or without rain, the run-off follows, in general, the distribution of the normal hydrograph from rain falling in the same number of days. This rule, however, is subject to two possible modifications; first, loose snow may retain water from its own melting or from rainfall; second, a sudden drop in temperature may freeze the snow and its retained water before the run-off effect on the streams is completed.

70. Ice is also a factor in the floods which occur early in the spring. Usually it is not of great importance. The Androscoggin River flows in a general southerly direction and consequently the ice in the lower reaches normally softens and goes out sooner than that in the upper reaches and headwaters. When the spring breakup occurs early, however, ice jams made up of thick, solid "blue ice", are likely to form at obstructions in the river. Ice jams which formed during the floods of March, 1936, carried out a railroad bridge at Brunswick

and caused much physical damage to other structures before eventually passing downstream. At Rumford an ice jam was successfully passed by regulation of the river at Errol, temporarily reducing the stage of the river until the jam had passed.

71. Record of Past Floods. - The six highest floods of record on the Androscoggin River at Rumford, Maine, (drainage area 2,090 square miles, of which 1,095 square miles are completely controlled) were as follows:

Date	Discharge (cubic feet per second) Average for one day	Peaks	Average Run-off for one Day (cubic feet per second per square mile)
March 19, 1936	68,300	74,000	32.6
April 15, 1895	55,230	-	26.4
November 5, 1927	39,100	-	18.7
March 2, 1896	39,010	-	18.6
May 18, 1893	38,060	-	18.2
March 13, 1936	35,600	38,200	17.0

Discharges in excess of 6,000 cubic feet per second (average for one day) are listed in APPENDIX B.

72. Frequency of Floods. - Spring, because of the occurrence of snow run-off, with or without rain, is the season of high water and floods. The monthly distribution of floods higher than the average annual at Rumford, Maine, 1892 to 1936, is shown in Figure 24. The computed probability of excessive flood flows at Rumford, based on study of the recorded discharges in excess of 6,000 cubic feet per second (average for one day) 1892 to 1936 (listed in APPENDIX B) is shown in Figure 25. The maximum floods expected for various periods of time at Rumford are listed below.

Period	24-Hour Discharge in c.f.s.
Once in 1 year	20,000
Once in 10 years	38,000
Once in 50 years	54,000
Once in 75 years	59,000
Once in 100 years	62,000

Very rare floods with peak discharges approaching 90,000 cubic feet per second may also occur. The foregoing figures are for 24-hour discharges. Frequency curves based on instantaneous peak flows are shown on Figures 56, 58, 60, and 62.

73. Floods of March, 1936. - The floods of March, 1936, were caused in part by factors which antedated the storms of that period. The precipitation in the form of snow of the winter months was above the average. For the three northern states of New England the snowfall for the three months, December, January, and February, of 1935-36, was 63.5 inches, or 8.2% above the 15-year average of that three month period. During the same period the temperature was below the average; the accumulated deficiency for the three states during the three winter months was 9.1° F. below the mean temperatures for the same months. By March the watershed was under a deep snow cover which had not been depleted appreciably by winter thaws before the arrival of the March storms. These storms followed similar courses in their approach to New England; they came from the Gulf of Mexico and passed up the Atlantic seaboard with a northward movement of tropical air masses. The arrival of the warm, moist tropical air, cooled by the cold snow-covered surface of the watershed, resulted in heavy precipitation and rapid melting of snow during the periods of the storms, March 11-13 and March 17-19. The heaviest precipitation occurred in the White Mountains, New Hampshire, the northern slopes of which are drained by the Androscoggin River; smaller quantities fell over the headwaters and lower portion of the watershed. The daily precipitation on this watershed is given in the following tabulation for the period March 10-20:

PRECIPITATION - MARCH 10-20, 1936

Station	Precipitation on each day - in inches											Total for 11 days
	10	11	12	13	14	15	16	17	18	19	20	
Berlin, N. H.	.21	.02	1.68	1.01	.02	T	.09	.89	.52	2.20	.42	7.06
Errol, N. H.	.08	-	1.24	.38	.08	-	.66	.70	.81	-	-	3.95
Farmington, Me.	.15	T	3.53	.68	-	-	.71	.24	.36	2.27	.06	8.00
Lewiston, Me.	.17	.13	3.07	.37	-	-	.02	.10	.65	1.60	-	6.11
Middle Dam, Me.	-	-	1.96	.52	.08	-	.56	.62	2.30	1.60	-	7.64
Milan, N. H.	-	.04	1.03	.39	-	-	.58	.82	.74	.63	-	4.23
N. Bridgeton, Me.	.20	.14	3.78	.43	-	-	.35	.14	.72	2.85	.08	8.69
Portland, Me.	.12	.25	1.23	.24	-	T	.03	.03	.22	.73	-	2.85
Rumford, Me.	-	.38	5.07	.39	T	-	.81	.26	1.60	1.29	.45	10.25
Upper Dam, Me.	-	-	2.10	-	-	-	1.27	-	1.18	1.19	-	5.74

74. Surveys for Flood Control Studies. - Shortly after the floods of March, 1936, field surveys to obtain data required for the study of flood control for this basin were initiated. This work included:

a. Economic survey of damages, direct and indirect, caused by the floods of March, 1936.

b. Determination of March, 1936, flood profile on the main river and each important tributary.

c. River cross-sections and bank topography at control points.

d. Data on existing structures affecting flood flow.

e. Topographic mapping by aerial photography and field surveys of the Rumford, Dixfield, Buckfield and Oxford reservoir areas (see Paragraph 86).

f. Aerial photographs, scale approximately 1:10,000, of the twenty-five reservoir sites investigated (Figure 26) and of Rumford, Berlin, Lewiston and Auburn.

g. Geological investigation of Rumford, Dixfield, Buckfield and Oxford dam sites.

Oblique aerial photographs were also taken (at an elevation of about 1,000 feet) of Lisbon Falls, Maine, between Lisbon Falls and Lewiston, Maine, and at a point 3 miles east of Lisbon Falls. All aerial photographs were made by the 8th Photo Section, United States Army Air Corps. These aerial photographs and maps prepared from the data obtained, as outlined above, are on file at the United States Engineer Office, 13th Floor Customhouse, Boston, Massachusetts.

75. Flood Damages. - The amount of damages, direct and indirect, caused by the floods of March, 1936, was obtained by a census of the individual sufferers in the basin. The direct losses included all damages to physical property and direct extraordinary expenditures required on account of the floods. The indirect losses, during the time of the flood or as a result of it, included such items as suspension of business, loss of sales and losses from interruption of transportation. The losses were further segregated into seven classes, which are shown in the table below.

DAMAGES CAUSED BY MARCH 1936 FLOODS

Class	Indirect	Direct	Total
Industrial	$634,425	$867,028	$1,501,453
Commercial	87,232	302,188	389,420
Farm and Rural	925	232,597	233,522
Residential	2,550	319,565	322,115
Railroads*	86,757	290,895	377,652
Highways*		550,294	550,294
Utilities	5,997	149,146	155,143
Public Funds (Municipal)		44,177	44,177
Totals	$817,886**	$2,755,890	$3,573,776

* Includes bridges.

** To cover indirect damages unreported but known to exist, the total of this column has been doubled in computing flood-control benefits (see Paragraph 91).

The losses were divided between the two states, Maine and New Hampshire, as follows:

State	Indirect	Direct	Total
Maine	$813,101	$ 2,605,419	$ 3,418,520
New Hampshire	4,785	150,471	155,256
Totals	$817,886	$ 2,755,890	$ 3,573,776

Data on flood damages, in more detailed form, are on file in the United States Engineer Office, 13th Floor Customhouse, Boston, Massachusetts.

76. Discussion of Possible Methods of Flood Control. - Three of the possible methods of alleviating or eliminating flood hazards in this basin have been found worthy of consideration. These methods are, (1) channel improvement, (2) levees or river walls, and (3) reservoirs.

77. The initial cost of comprehensive channel improvement in the entire valley would greatly exceed the cost of reservoirs and the resultant disturbance of the existing regimen would require the expenditure of considerable sums for maintenance annually. Reduction of losses at certain specific flood-damage centers in the lower valley may be effected by local channel improvements such as those discussed in Paragraphs 96 to 99, inclusive. In general, however, such improvements which are of sufficient magnitude to effect substantial reductions in flood damages are not economically feasible at the present time.

78. The provision of flood protection by levees or river walls has certain specific advantages. Such protection is positive up to the height of levee or river wall provided, plus possibly any additional height which may be added by sandbagging or other emergency operations immediately preceding or during a flood. The protection afforded is, however, limited in extent rather than general, as in the case of reservoirs, and there are no incidental benefits such as those which accrue from reservoir control. Accordingly, levees or

river walls will generally prove to be of greatest value in supplementing the protection to areas of concentrated wealth and development where only a moderate reduction of flood height can be secured by a partial flood-control reservoir project. Consequently, the more the development is distributed, the less desirable are levees and river walls as a means of general flood relief.

79. The most desirable method of obtaining general flood relief in the Androscoggin basin is by means of reservoirs. The maximum flood control effect at any point will be achieved by the location of a reservoir or reservoirs immediately upstream from the point to be protected. Accordingly, since the greater part of the development in this basin is concentrated in the lower half of the valley, for greatest efficiency in flood control, reservoirs should be located as near this area as possible. Geographic distribution is also a very important consideration in the selection of reservoirs. The possibility of storms centering over any tributary is evident and a system of reservoirs distributed so that the major tributary streams are controlled is desirable. The existing large lake areas and conservation storage now furnish sufficient control on some of these tributaries, such as the main stream above Errol Dam, the Magalloway River above Aziscohos Dam, and Dead River above Leeds. On the other tributaries and on the main stream above Rumford, the character of topography and state of development are such that there are numerous possible sites from which to select the most desirable system of reservoirs.

80. Plan Floods. - Since past floods of record may be exceeded in magnitude in the future, protective works should be designed for plan floods, such as would result from conditions purposely assumed more severe than those which caused the greatest flood of record. Several types of plan floods are possible of consideration on the Androscoggin basin. These are, briefly, as follows:

__a.__ A peak flow can be obtained from a general study of flood discharge in the region of the watershed in question. Such a study was made of flood discharge in New England for the 1936 flood control report on the Merrimack River. The maximum recorded peak discharge in cubic feet per second per square mile was plotted against drainage area and an envelope curve drawn through the uppermost plotted points. On the assumption that one river may experience as high a flood discharge as another of the same drainage area, an estimated peak flood flow may be taken from that envelope curve. The principal objection to this method, in addition to the possible error involved in relating location, shape of drainage basin, slopes, etc., is that although it gives a peak discharge, it does not produce a flood hydrograph, which is necessary for reservoir design. If sufficient data, including a unit hydrograph, were available, it might be possible to construct an approximate flood hydrograph by trial and error methods.

__b.__ The use of a great storm which has passed over the watershed, or transposition thereto of a storm which has occurred in adjacent regions, has been resorted to in the determination of plan floods. The objection to this method is that each storm has its own peculiarities and characteristics, such as amount of rainfall, area covered, path, etc. Because one storm has occurred with certain attributes does not necessarily mean that another will occur with the same measurable quantities on another drainage basin of different elevation and basin characteristics. Corrections might be made to compensate for these differences, but at best much adjustment would be required.

c. The plan used in this study of the Androscoggin was based on the expected rainfall and unit hydrographs (see Paragraphs 81 and 82).

81. Unit Hydrographs. - Unit hydrographs* were obtained from four stations on the watershed. The methods used are explained in the 1936 flood control report on the Merrimack River. From the average unit hydrograph, distribution factors were obtained to construct a design hydrograph. These distribution factors are shown in the following table and represent the percentages of the total flow for a given storm which will run off for each day during which this flow persists.

DISTRIBUTION FACTORS OF STORM RUN-OFF

Station	Drainage Area (sq.mi.)	1	2	3	4	5	6	7	8	9	10 days
		Distribution Percentages									
Androscoggin R. at Rumford	2090**	15.9	42.6	20.5	9.6	5.6	3.2	1.9	0.7		
Androscoggin R. at Auburn	3257**	9.1	29.1	27.3	15.1	8.3	5.1	3.2	1.9	0.8	0.1
Little Androscoggin R. at S. Paris	76	21.7	45.2	15.7	7.9	5.0	3.0	1.4	0.1		
Swift R. at Roxbury	95	15.3	45.7	20.4	9.0	4.9	2.8	1.5	0.4		

* An exposition of the unit hydrograph method is contained in United States Geological Survey Water Supply Paper No. 772 (1936).

** Includes 1,095 square miles completely controlled.

82. Plan Floods used in this Study. - The plan floods used in this study were based on the expected rainfall and unit hydrographs. For the methods used in computing the expected rainfall and the derivation of the unit hydrographs, see the 1936 flood control report on the Merrimack River. The procedure is briefly summarized here. The expected daily rainfall was computed for a suitable station with long records (covering 30 years) by J. J. Slade, Jr.'s probability function (Trans. Am.Soc.C.E., Vol.101, 1936). For reservoir outlet

design, a plan flood was devised on the basis of two closely succeeding three-day storms. The central day of the second and main storm was based on precipitation to be expected once in 100 years, and the first and third days on equal amounts sufficient to raise the total precipitation to what is expected in a three-day storm once in 100 years. A three-day interval intervened between the main and preliminary storm which was based on precipitation of a frequency of about ten to twelve years equally divided over three days and which was assumed to saturate the watershed. Then by means of distribution factors of the unit hydrograph (see Paragraph 81) the discharge was computed for the storm. For spillway design the same plan of storms was followed, but the precipitation of the main storm was increased by 30 per cent, and one inch of run-off from melting snow was assumed for each day of the main storm and one-half inch each day for the preliminary storm. The use of these plan floods in the design of the reservoirs is outlined below.

83. Reservoir Design. - The methods of reservoir design employed are described briefly in APPENDIX D of this report and completely in the 1936 flood control report on the Merrimack River. The spillway-crest elevation was selected from consideration of economic design and the general requirement that minimum storage equivalent to 5 inches of run-off over the net drainage area be provided, if possible. The economic area of outlets was determined as that with which the outlet design flood would cause the water-surface elevation in the reservoir to rise level with the selected spillway-lip elevation. Although it is intended to operate the reservoirs primarily as retarding basins, these outlets are provided with gates in order to permit greater flexibility in operation. Additional conduit area (equipped with gates) equal to that required for operation as retarding basins alone was provided for the purpose of quickly discharging water accumulated in the reservoir. The length of spillway was determined as that required to limit the surcharge resulting from the spillway design flood to 10 feet, assuming outlets closed and the water surface at

the beginning of the flood to be at the spillway-lip elevation. A minimum freeboard of 5 feet was provided above this surcharge.

84. Discussion of Flood-Control Reservoirs Considered in this Investigation. - Study was made, using the United States Geological Survey topographic maps of the watershed, to locate all places topographically suited to the construction of dams with heights sufficient to control the computed March, 1936, flood run-off. Eliminations were made from these possibilities on the basis of size of drainage area, characteristics of run-off from drainage area, location with respect to flood-damage centers, and cost, including property damage to be incurred in construction.

85. In this way the list was narrowed down to 25 reservoirs (see list of reservoirs tabulated in Figure 26) considered worthy of detailed investigation. With a view to securing the best geographical distribution of reservoirs and control on major tributaries where the flood run-off is otherwise uncontrolled, these possible reservoirs were divided into groups according to tributaries. Study was then made of each group, on the basis of flood-control benefits and construction cost, to determine the most economical of the group.

86. The reservoirs finally selected as most desirable were Rumford on the main stream, Dixfield on the Webb River, Buckfield on the Nezinscot River, and Oxford on the Little Androscoggin River. The main stream above Errol is controlled by the conservation storage in Umbagog, Aziscohos, Kennebago, Rangeley, Mooselookmeguntic and Richardson Lakes which are regularly drawn down during the winter months in anticipation of the spring run-off. With such storage, controlling a drainage basin of approximately 1100 square miles, operative, further control in this area was deemed unnecessary. Similar conditions prevail on the Dead River, where Androscoggin Lake and a series of ponds develop a considerable amount of storage. It was found that reservoir

control on the Swift River would entail high damage and construction costs, factors which eliminated the sites on this tributary. The Rumford, Dixfield, Buckfield and Oxford system of reservoirs would control and regulate 42 per cent of the area of the basin exclusive of the 1,100 square miles above Errol now controlled for storage. Considering the area above Errol in the system, the total area controlled becomes 74 per cent of the total drainage area.

87. The locations of the project reservoirs are shown on Figure 27. The Androscoggin River valley is most highly developed in the portion below the city of Rumford. In addition to being well cultivated it is dotted by a number of manufacturing towns and cities which are well connected by highways and railroads. Thus the project reservoir system is strategically located with respect to this portion of the valley, both as regards geographic distribution and control on large tributaries of the main stream. Rumford Reservoir on the Androscoggin River above the city of Rumford would provide flood-control benefits to the entire lower valley. Dixfield Reservoir on the Webb River, Buckfield Reservoir on the Nezinscot River, and Oxford Reservoir on the Little Androscoggin River would control those tributaries and are so located that their ratios of flood-prevention benefits are high. In addition, Oxford Rservoir would control flood flows through the lower portion of the Little Androscoggin River valley, which is well developed commercially and contains important lines of communication. Of the total losses of $3,573,776 caused by the floods of March, 1936 (see Paragraph 75) $2,253,121, or 63 per cent occurred in the area downstream from the project reservoirs. Flood-control benefits are based upon the latter figure, since the reservoirs have no effect upon damages upstream.

88. The following tables contain summaries of the estimated costs and general features of the Rumford, Dixfield, Buckfield and Oxford Reservoirs. Additional data are given in APPENDIX D; cost estimates in APPENDIX G.

RUMFORD RESERVOIR

(see Figures 28 and 29)

Drainage Area: 965 square miles (net).

Capacity: 295,000 acre-feet; 5.7 inches run-off

Reservoir Area 15,200 acres at Spillway-Crest Elevation 655 ft. M.S.L.

Dam: Earth Maximum Height: 90 feet

Overall Length: 1450 ft. Length of Spillway: 750 feet

Bedrock is not available under the dam or spillway. The dam is of hydraulic earth fill, 35 feet wide at the top (elevation 670 ft.) with side slopes of 1 on 3. The upstream face and toe are of riprap. The spillway, located 12,000 feet northwest of the dam, consists of a hollow concrete overflow section 750 feet long with earth-fill retaining sections 370 feet long. Two 22 ft. 0 in. diameter outlet tunnels 1100 feet long pass through the hill on the south side of the dam. The outlets are controlled by fourteen 5-1/2 ft. by 10 ft. sliding gates.

Land involved:	17,000 acres	Railroads affected:	7 miles
Towns affected:	Rumford Center, Hanover, Newry, Bethel, No. Bethel, W. Bethel	Highways affected:	33 miles

Estimated First Cost (including engineering, administration, superintendence and contingencies)*

Land and relocation costs to be borne by local agencies:		$ 5,935,000
Land and buildings	$ 2,235,000	
Relocation railroads	837,000	
Relocation highways, bridges, etc.	2,430,000	
Other relocations	433,000	
Construction costs to be borne by the United States:		5,227,000
Dams and appurtenances	5,227,000	
Total		$11,162,000

Cost per acre-foot of storage $37.80 Cost per square mile of drainage area $ 11,600

*See Paragraph 102. Since, in this case, land and relocation costs exceed construction costs, costs to be borne by the United States should be increased, and costs to be borne by local agencies decreased, to one-half the total cost.

DIXFIELD RESERVOIR

(see Figures 30 and 31)

Drainage Area: 125 square miles

Capacity: 40,300 acre-feet; 6.0 inches run-off

Reservoir Area 2,500 acres at Spillway-Crest Elevation 450 ft. M.S.L.

Dam: Earth and Concrete — Maximum Height 55 ft.

Overall Length: 2,570 ft. — Length of Earth Section: 2,430 ft.

Length of Concrete Section: 140 ft. (including spillway 83 ft. long)

Bedrock is not available at the dam site. The spillway consists of a hollow concrete overflow section. The outlet structures, adjacent to the spillway, consist of four concrete box outlets each 3 ft. 9 in. by 7 ft. controlled by four vertical sliding gates 3 ft. 9 in. by 7 ft. The retaining section of the dam is of rolled-earth fill, 25 feet wide at the top (elevation 465 feet) with side slopes of 1 on 3. The upstream face and the toe are of riprap.

Land involved: 3,000 acres — Railroads affected: none

Towns affected: Carthage — Highways affected: 0.7 mile

Estimated First Cost (including engineering, administration, superintendence and contingencies)*

<u>Land and relocation costs to be borne by local agencies:</u>		$ 239,000
Land and buildings	$151,000	
Relocation railroads	0	
Relocation highways, bridges, etc.	47,000	
Other relocations	41,000	
<u>Construction costs to be borne by the United States:</u>		659,000
Dams and appurtenances	659,000	
Total		$ 898,000

Cost per acre-foot of storage $22.30. Cost per square mile of drainage area $ 7,180

* See Paragraph 102.

BUCKFIELD RESERVOIR

(see Figures 32 and 33)

Drainage Area : 156 square miles

Capacity: 61,000 acre-feet; 7.3 inches run-off

Reservoir Area 4,050 acres at Spillway-Crest Elevation 345 ft. M.S.L.

Dam: Earth Maximum Height: 65 feet

Overall Length: 2100 feet Length of Spillway: 130 feet

The outlet structures and the channel spillway rest on bedrock. The dam is of hydraulic earth fill 30 feet wide at the top (elevation 360 ft.) with side slopes of 1 on 3. The upstream face and toe are of riprap. The spillway consists of a channel cut through earth and rock at the north end of the dam. The outlet structures consist of one 11 ft. 0 in. diameter semi-elliptical conduit controlled by four 3 ft. 9 in. by 7 ft. sliding gates. In addition to the dam there are four earth dikes having a total length of 4500 feet.

Land involved: 5,600 acres Railroads affected: None

Towns affected: None Highways affected: 5-1/2 miles

Estimated First Cost (including engineering, administration, superintendence and contingencies)*

Land and relocation costs to be borne by local agencies:		$ 790,000
Land and buildings	$324,000	
Relocation railroads	0	
Relocation highways, bridges, etc.	432,000	
Other relocations	34,000	
Construction costs to be borne by the United States:		$1,251,000
Dams and appurtenances	$1,251,000	
	Total	$2,041,000

Cost per acre-foot of storage $33.50. Cost per square mile of drainage area $13,100

* See Paragraph 102

OXFORD RESERVOIR

(see Figures 34 and 35)

Drainage Area: 231 square miles

Capacity: 92,000 acre-feet; 7.5 inches run-off

Reservoir Area: 6,100 acres at Spillway-Crest Elevation 325 ft. M.S.L.

Dam: Earth and Concrete — Maximum Height: 63 ft.

Overall Length: 1,080 ft. — Length of Earth Section: 820 ft.

Length of Concrete Section: 260 ft. (including spillway 165 ft. long)

Bedrock is exposed in the present river channel where the concrete spillway and outlet structures are located. The spillway section consists of a gravity-type Ogee section. The outlet structures consist of four 4 ft. 6 in. by 7 ft. box conduits controlled by four sliding gates, each 4 ft. 6 in. by 7 ft. located in a control tower at one end of the spillway. The remainder of the dam is of rolled-earth fill 35 ft. wide at the top (elevation 338 feet) and with 1 on 3 side slopes. The upstream face and toe are of riprap. In addition to the main dam there are two earth dikes totalling 7,100 feet in length.

Land involved: 7,000 acres — Railroads affected: 3-3/4 miles

Towns affected: Oxford, Welchville — Highways affected: 8 miles

Estimated First Cost (including engineering, administration, superintendence and contingencies)*

<u>Land and relocation costs to be borne by local agencies:</u>		$1,970,000
Land and buildings	$ 763,000	
Relocation railroads	613,000	
Relocation highways, bridges, etc.	513,000	
Other relocations	81,000	
<u>Construction costs to be borne by the United States:</u>		$1,724,000
Dams and appurtenances	$1,724,000	
	Total	$3,694,000

Cost per acre-foot of storage: $ 40.20 — Cost per square mile of drainage area: $ 16,000

* See Paragraph 102. Since in this case, land and relocation costs exceed construction costs, costs to be borne by the United States should be increased, and costs to be borne by local agencies decreased, to one-half the total cost.

89. Effect of Project Reservoirs. - To determine the effectiveness of different reservoirs, basic operation as retarding basins being contemplated, it is necessary to route both the natural and modified hydrographs from proposed reservoirs to those points where modified hydrographs showing flood reduction are desired. To accomplish this purpose, giving proper consideration to time of travel as well as valley storage, the method of flood routing developed at the United States Engineer Office, Zanesville, Ohio, was used. This method is described fully in APPENDIX G (not printed) of the report* on the Muskingum River, Ohio, dated December 1, 1934, and briefly in the 1936 flood control report on the Merrimack River.

90. Studies were made of the effect of all four of the project reservoirs described in Paragraph 86, of the Rumford, Dixfield and Buckfield reservoirs in combination, and of the Rumford Reservoir alone. The results of these studies are summarized in the following table. Additional data concerning the effect of the project reservoirs are given in APPENDIX E. Figures 36 and 37 show the approximate natural profile of the March, 1936, flood on the Androscoggin River and the profile as it would have been modified by the project reservoirs.

* Made in accordance with the provisions of H. Doc. No. 308, 69th Congress, 1st Session.

APPROXIMATE REDUCTIONS IN STAGE FOR

FLOOD SIMILAR TO THAT OF MARCH, 1936

Station	Net Reduction in Stage		
	Rumford (feet)	Rumford, Dixfield and Buckfield Reservoirs (feet)	Rumford, Dixfield Buckfield and Oxford Reservoirs (feet)
Rumford (on main river)	4.6	4.6	4.6
Livermore Falls (on main river)	2.1	2.5	2.5
Lewiston (on main river)	3.2	5.0	5.0
Auburn (on Little Androscoggin)	0	0	15.2
Lisbon Falls (on main river)	1.6	2.0	2.8

91. Annual Losses and Benefits. - Damages suffered from the flood of March, 1936, are tabulated, as reported, in paragraph 75. There has been some doubt, however, regarding the figures for indirect damages. It is very difficult to obtain accurate and complete returns covering indirect losses. Some of these are more or less intangible, and not readily evaluated. Their compilation is a source of considerable trouble and expense to the business organizations reporting them. Because of these difficulties, it is believed that the tabulated values for this item are insufficient. Moreover, more detailed estimates on representative reaches of the Merrimack River, made in connection with the 1936 flood control report, indicate that the actual indirect losses are about twice those reported in the original economic survey of flood damages. It is considered, therefore, that an increase of 100 per cent in the reported indirect damages is conservative and may well embrace such items as: (1) Indirect damages to undeveloped property in flood areas, the development of which has been suspended, due to the fact that the areas are subject to frequent flooding; and (2) Indirect damages, including lost business occasioned by cessation of operation of utilities

and disruption of transportation facilities, which could not be fully evaluated in the field survey made by this office after the flood. Accordingly, annual flood losses and resulting benefits from the reservoirs are based upon direct damages as reported and indirect damages equal to twice the reported values.

92. The following table of annual losses and benefits is based upon the expected number of floods as computed from available records by means of the theoretical probability function of J. J. Slade, Jr. (See Trans. Am. Soc. C. E., Vol. 101, and the 1936 flood control report on the Merrimack River.) Natural and modified flood frequency curves, a damage-discharge curve, and natural and modified damage-frequency curves for the reaches represented below are shown on Figures 56 to 63, inclusive.

Damage Center	Computed Probable Annual Losses	Computed Annual Benefits: Reservoir Combination R-D-B-O*	Reservoir Combination R-D-B**	Rumford Reservoir Alone
Lisbon Falls	$ 110,500	$ 79,500	$ 64,600	$ 57,300
Auburn	51,800	37,900	37,900	18,700
Livermore Falls	121,200	103,800	103,800	93,800
Rumford	170,000	152,900	152,900	152,900
Total	$453,500	$ 374,100	$ 359,200	$ 322,700

* Rumford, Dixfield, Buckfield and Oxford, Reservoirs
** Rumford, Dixfield and Buckfield Reservoirs

93. These losses and benefits have also been computed by means of the actual flood record for the past 44 years in lieu of the calculated probabilities. The results are given in the following table:

Damage	Computed Annual Losses	Computed Annual Benefits: Reservoir Combination R-D-B-O*	Reservoir Combination R-D-B**	Rumford Reservoir Alone
Lisbon Falls	$150,800	$ 101,300	$ 78,000	$ 71,200
Auburn	64,100	48,800	48,800	25,300
Livermore Falls	122,000	106,500	106,500	92,500
Rumford	156,500	123,100	123,100	123,100
Total	$493,400	$ 379,700	$ 356,400	$ 312,100

* Rumford, Dixfield, Buckfield and Oxford Reservoirs
** Rumford, Dixfield and Buckfield Reservoirs

94. It will be noted that the losses and benefits computed by the two methods in Paragraphs 92 and 93 agree quite closely. Such agreement may be expected when the observed floods are typical of those to be expected as computed by the theoretical probability method. Where the period of record is limited but happens to include floods of rare frequency a larger discrepancy may occur because the arithmetic extension method simply utilizes the short sample of larger floods within the short period of record whereas the probability method affords a rational means of assigning frequency values to the flows occurring within such a period, thereby eliminating somewhat the errors of sampling which may be large in a short record.

95. In the case of the Androscoggin River, with a record of 44 years, the differences in losses and benefits computed by the two methods are less than 9 per cent. In the case of the Merrimack River, with a record of 90 years, the discrepancy was about 16 per cent. However, in the computations for the Saco River, with a record of only 26 years, the results differed by more than 75 per cent. In all cases, the results obtained by the probability method were used as the basis for the economic analysis of proposed work.

96. <u>Local Flood Protection</u>. - Discussion of the value of channel improvement as a method of reduction of flood losses entails a division of channel obstruction into two classes: (1) such artificial obstructions as dams, buildings and bridges which become replaceable through obsolescence or deterioration; (2) natural permanent obstructions such as falls, rapids, and ledges. Improvements of class (1) generally can be effected economically only when the structure has reached the end of its economic or physical life. Improvement of class (2) obstructions can be effected at any time provided the cost of the improvement is justified by the benefits it confers. The possibilities for local flood protection works of both classes on the Androscoggin River have been investigated and analyzed. The details of these studies are given in Appendix F and are summarized in the following paragraphs.

97. The general procedure followed was to determine the annual flood damage at various damage centers and to estimate the cost of providing dikes, walls, or channel improvement necessary to eliminate this flood damage. The cost estimates were based on preliminary information only and no surveys were made. It is believed, however, that the information and estimates are sufficiently accurate to establish the degree of economic justification for local flood protection on this river. The damage centers studied were Berlin, New Hampshire, both on the Androscoggin and the Dead Rivers, and Virginia, Rumford, Mexico, Chisholm, Livermore Falls, Lewiston, Auburn, Lisbon Falls, The Pejepscot Paper Company, Brunswick and Topsham, all in Maine. (See Figure 2.). The ratio of benefits to cost for local flood protection works at these localities ranges from

0.037 to 0.590. (See Appendix F.) Although the estimates are based on preliminary information and on the comparatively high interest rates of 4 per cent on Federal investment and 5 per cent on non-Federal investment, it is believed that the ratio in all cases would still be well below unity even when based on more accurate information and using lower interest rates such as are prevailing at the present time.

98. The Androscoggin River contains numerous power dams that obstruct the flow particularly where the power house is built as an extension of the dam and where the length of the spillway is further reduced by abutments, forebays, and other structures. Because the towns and cities have grown up around such sites, largely as a result of the dams, and other encroachments on the channel have accumulated, these localities tend to become damage centers during floods. Although it has been found that it is not economically feasible to correct these and other channel encroachments for flood-control reasons only, it is believed entirely practicable to eliminate these flood hazards at some future date when reconstruction or replacement becomes necessary in the natural course of events.

99. Specific suggestions for channel improvement by the correction of encroachment of existing structures are contained in Appendix F for several of the flood-damage centers mentioned in Paragraph 97, and for which special local protection works do not appear to be justified at the present time. These specific suggestions involve increasing spillway capacities and the provision of floodgates and dams, the provision of greater clearances of bridges and the elimination of bridge piers and abutments which create serious channel encroachment during flood stages. It is believed that if the corrections and improvements suggested are carried out, to a regulation by local authorities, that the major portion of the flood problem at these damage centers will have been eliminated.

100. <u>Flood Warnings.</u> - Another practical method of lessening flood damages is by means of the flood-warning service maintained by the United States Weather Bureau. When a rainstorm is threatening to pass into the watershed, its probabilities are studied and the companies controlling the storage are informed of the expected rainfall. If the lakes are full and the rainfall threatens to be considerable, the water levels are drawn down in advance of the storm. The amount drawn is determined from the run-off records of the companies and depends on the saturation of the ground, snow cover, the season of the year, etc., as well as on the probable rainfall. By this means storage is made available when the run-off begins, and this not only reduces the flood levels of the lakes, but also lessens the maximum discharge of the river, thus alleviating flood losses. Of course, distant headwater reservoirs must be drawn down in ample time, for if discharged immediately prior to or during the early stages of a flood, they could contribute to an increase in downstream flood stages by filling the valley storage.

101. Two important factors affecting floods in this basin are the extent and water equivalent of the snow cover and the condition of the ground underneath the snow. Limited observations are now made of precipitation in the form of snow by the United States Weather Bureau, power companies, winter sport organizations and other agencies, but additional estimates by trained observers of the amount of snow cover and its water equivalent are necessary to increase the value of the flood-forecasting service. Extension and correlation of investigations of hydrologic conditions in the basin through cooperation of all agencies concerned, to the end that improved flood forecasts and adequate warning be provided to the companies controlling the storage and to the public, appear to be desirable.

102. Discussion. - Studies of possible methods of flood control in the Androscoggin basin indicate that the only practicable method of furnishing general flood relief throughout the basin is by means of reservoirs. No combination of reservoirs studied, however, would be economically justified at the present time. The total estimated Federal and local costs* for each of these reservoirs are as follows: (See Appendix G).

ESTIMATED FIRST COST OF PROJECT RESERVOIRS

Project Reservoir	Federal	Local	Total
Rumford	$ 5,581,000	$ 5,581,000	$ 11,162,000
Dixfield	659,000	239,000	898,000
Buckfield	1,251,000	790,000	2,041,000
Oxford	1,847,000	1,847,000	3,694,000
Total	$ 9,338,000	$ 8,457,000	$ 17,795,000

103. The total annual carrying charges have been computed for the reservoirs using the standard interest rates of 4 per cent on Federal costs and 5 per cent on non-Federal costs. The annual charges, which are listed in detail in Appendix G, are as follows: for Rumford, Dixfield, Buckfield and Oxford Reservoirs, $1,000,000; for Rumford, Dixfield and Buckfield Reservoirs, $793,000; and for the Rumford Reservoir alone, $626,000. The estimated probable annual flood-control benefits from all reservoirs would be $374,000 from the three-reservoir combination, $359,200, and from Rumford Reservoir alone, $322,700. The determination of these costs and annual benefits has been made on the basis of operating the reservoirs as retarding basins for benefits of flood control alone. These results are summarized in the following table:

* Local costs determined by application of the provisions of the Flood Control Act approved June 22, 1936 (Public No. 738, 74th Congress) that local agencies shall provide, without cost to the United States, all lands, easements, and rights-of-way necessary, except that that part of such costs which exceeds the cost of construction shall be borne equally by the United States and the local interests.

COMPARISON OF ANNUAL CARRYING CHARGES AND BENEFITS

FOR FLOOD CONTROL ALONE

Reservoirs	Total First Cost	Annual Carrying Charges	Annual Flood-Control Benefits	Ratio of Annual Benefits to Annual Charges
Four (R-D-B-O)*	$ 17,795,000	$ 1,000,000	$ 374,100	0.37
Three (R-D-B)**	14,101,000	793,000	359,200	0.45
Rumford alone	11,162,000	626,000	322,700	0.52

* Rumford, Dixfield, Buckfield and Oxford

** Rumford, Dixfield and Buckfield

This tabulation shows that for no combination of reservoirs do the benefits equal the carrying charges. The reservoirs, therefore, are not warranted for flood control alone, and least of all, the Oxford Reservoir.

104. The Rumford Reservoir is the only one of the group which shows economic possibilities for a development to provide combined storage for power and flood control. The table following Paragraph 61 showed the power costs to be realized from a combined development, with a greater part of the reservoir costs charged to flood control. The following table is based upon the same operating methods, but includes total annual charges for the combined storage, and the combined benefits from power and flood control. The value assumed for the energy produced, 5 mils per kilowatt-hour, is the average cost of generation of energy produced by the leading utility companies operating in this section (see Paragraph 62). In no case is the development able to earn the carrying charges.

ECONOMIC ANALYSIS

DEVELOPMENT OF RUMFORD SITE FOR COMBINED STORAGE FOR POWER AND FLOOD CONTROL

Method of Operation *	Total Cost **	Total Annual Carrying Charges ***	Primary Power Generated at Site		Increased Primary Power Generated at Existing Downstream Plants		Increased Primary Power from Potential Downstream Plants		Total Annual Power Benefits	Annual Flood Control Benefits	Total Annual Benefits	Ratio-Annual Benefits to Annual Charges
			Annual Energy (Kilowatt-Hours)	Annual Benefits at 5 Mils Per Kilowatt-Hour #	Annual Energy (Kilowatt-Hours)	Annual Benefits at 5 Mils Per Kilowatt-Hour #	Annual Energy (Kilowatt-Hours)	Annual Benefits at 5 Mils Per Kilowatt-Hour #				
1(a)	$16,913,000	$1,226,000	46,000,000	$230,000	37,000,000	$185,000	-	-	$415,000	$322,700	$737,700	0.60
1(b)	16,913,000	1,226,000	46,000,000	230,000	37,000,000	185,000	13,000,000	$65,000	480,000	322,700	802,700	0.65
2(a)	16,063,000	1,124,000	-	-	79,000,000	395,000	-	-	395,000	322,700	717,700	0.64
2(b)	16,063,000	1,124,000	-	-	79,000,000	395,000	29,000,000	145,000	540,000	322,700	862,700	0.77

*Method of Operation

1. For maximum primary energy from power development at site.
   (a) Benefits to existing but not potential downstream power developments included.
   (b) Benefits to existing and potential downstream power developments included.
2. For maximum primary energy from existing downstream plants. No power installation at site.
   (a) Benefits to potential downstream power developments not included.
   (b) Benefits to potential downstream power developments included.

** From table following Paragraph 61. Includes interest during construction.
*** 7 per cent on reservoir and dam; 12 per cent on power house and equipment.

See Paragraph 104. Value at switchboard.

105. Although it has been shown that flood-control benefits from none of the projected reservoir combinations will pay the carrying charges upon their construction, and that the returns from a combined development at Rumford Reservoir will be insufficient to justify its cost, there is another possible source of revenue which may be made available to apply upon the carrying charges of the flood-control reservoirs. This results from the incidental benefits to downstream power developments of the increased storage.

106. The reservoirs are planned to operate primarily as retarding basins. The outlets, however, are to be provided with gates by means of which a portion of the flood water may be retained and released during the dry season, so as to yield incidental benefits to the downstream power companies through increased low-water flow below the site. More complete clearing would be required in the lower portions of the reservoirs for this method of operation than for operation as retarding basins, upon which the cost estimates are based. The resulting additional cost is of relatively minor importance in the economic analysis of the flood-control plan and has, therefore, been omitted in this analysis.

107. A precise determination of these incidental benefits, while presenting no appreciable difficulty other than the amount of time and labor required, is not considered necessary for the purpose of this report. To provide a basis for an approximate determination of the amount by which the low-water flow of the river will be increased, it has been assumed that the reservoirs will be half full at the beginning of the dry season.

108. Based on this assumption, it has been computed that the increased low-water flow of the Androscoggin River at Auburn, Maine, would be as shown in the following table:

EFFECT OF SUPPLEMENTAL OPERATION OF FLOOD-CONTROL RESERVOIRS ON MINIMUM MEAN MONTHLY FLOW AT AUBURN, MAINE*
(All flows in cubic feet per second)

	Four-Reservoir Combination (R-D-B-O)	Three-Reservoir Combination (R-D-B)	Rumford Reservoir Alone
Present flow	1,900	1,900	1,900
Flow with indicated reservoirs	2,740	2,630	2,510
Increase	840	730	610

* Based on dry year 1929 - 1930. Minimum mean monthly flow December, 1929 - 1,900 cubic feet per second.

109. The annual power benefits to existing plants from the increased flow would be as follows:

Reservoirs	Incidental Power Benefits	
	Increased Annual Output (kilowatt-hours)	Value at 5 Mils Per Kilowatt-Hour
Four (R-D-B-O)	48,000,000	$ 240,000
Three (R-D-B)	46,000,000	230,000
Rumford Reservoir alone	39,000,000	195,000

The total developed head below each site is as follows: Rumford, 484 feet; Dixfield, 308 feet; Buckfield, 233 feet; Oxford, 227 feet. The total head developed below each site at installations of sufficient capacity to benefit from increased flow, is estimated at the following: Rumford, 407 feet; Dixfield, 261 feet; Buckfield, 172 feet; Oxford, 64 feet.

110. The following table shows the comparison between carrying charges and flood-control and incidental power benefits for the same flood-control reservoir combinations:

COMPARISON OF ANNUAL BENEFITS AND CARRYING CHARGES

Reservoirs	Annual Incidental Power Benefits	Annual Flood-Control Benefits	Total Annual Benefits	Total Annual Carrying Charges	Ratio of Annual Benefits to Annual Charges
Four (R-D-B-O)	$ 240,000	$ 374,100	$ 614,100	$ 1,000,000	0.61
Three (R-D-B)	230,000	359,200	589,200	793,000	0.74
Rumford alone	195,000	322,700	517,700	626,000	0.83

This tabulation shows that, even assuming a market for the increased energy output and full cooperation of downstream power beneficiaries, the value of incidental power benefits from flood-control reservoirs would not be sufficiently large, under existing conditions, to increase the total annual benefits to the extent required to justify the construction of the reservoirs. Although the annual carrying charges used in the foregoing comparison have been computed on the basis of 4 per cent interest on Federal costs and 5 per cent on non-Federal costs (see Paragraph 103 and Appendix G), the use of a lower interest rate such as 3 per cent would not alter the ratios of benefits to charges sufficiently to indicate justification for the reservoirs.

111. The addition of the Oxford Reservoir to the group consisting of Rumford, Dixfield and Buckfield causes the annual carrying charges to increase $207,000 while increasing the annual benefits only $24,900, an adverse ratio of over 8 to 1. It is, therefore, apparent that the inclusion of the Oxford site results in development far beyond the point of diminishing economic returns, and consequently this reservoir should be assigned very low priority until warranted at some future time by a marked increase in the value of property subject to flood damage.

112. Conclusions. - Flood control of the Androscoggin River by means of the construction of the Rumford, Dixfield, Buckfield and Oxford Reservoirs is physically, but not economically, feasible at this time. The state of development of the basin is such that the damages resultant from floods are not large enough to justify the cost of construction of these reservoirs. Incidental power benefits would not be sufficiently large under existing conditions to make up the difference between the annual carrying charge for flood control and the annual benefits from reduction of flood losses. Normally, as further development takes place in the basin, damages from floods will increase in amount, as will also the incidental power benefits by reason of new developments on the river, but so also, because of development within the areas of potential reservoir sites, will the cost of construction of reservoirs increase.

113. It would appear advisable, therefore, to restrict development in sites which may be needed later for flood-control reservoirs, to insure their availability at reasonable cost when the portion of the valley subject to flood damage hasdeveloped to the extent that flood control becomes economically feasible. This can be accomplished by the establishment of state or local parks or forests in the reservoir areas with the State Government, the agency normally expected to furnish lands and rights-of-way, controlling further development therein.

114. In this connection, it would also appear desirable to restrict, in so far as possible, further development in the basin to areas outside those subject or likely to be subject to flood damage.

In particular, proper supervision should also be exercised by the state and local governments to prevent the construction of structures which, by obstructing the channel or otherwise, cause or increase flood damage to others. Existing structures of this kind should, when reconstructed, be improved in this respect. The State of Maine appears to be the proper agency to enact legislation to insure such action.

115. The flood-warning service of the United States Weather Bureau should provide an important practical means of alleviating flood damages, not only by furnishing information to companies controlling storage in the basin which willenable them to operate in such manner as to reduce the magnitude of floods, but also by affording adequate warning to all individuals and industries located within the flood plain. It appears that the value of this service can be increased by the correlation of all data obtained by existing agencies now concerned with investigation of hydrologic conditions in the basin in addition to the extension of the work of the United States Weather Bureau and the United States Geological Survey to secure additional data, including a larger number of observations of amount and water content of snow cover.

CONCLUSIONS

116. A review of information presented in H. Doc. No. 646, 71st Congress, 3d Session, and careful study of additional information concerning the flood situation in this basin, available as a result of the floods of March, 1936, indicate that the recommendations made in the report under review are basically sound in so far as they concern navigation, irrigation and power development, but that some revision of the conclusions with respect to flood control should be made.

117. Navigation. - Extension of navigation through or above tidewater would not be economically advisable at the present time.

118. Irrigation. - None is necessary.

119. Power Development. - There is an ample supply of power for present demand and numerous undeveloped water-power sites exist, the most promising of which have been investigated by the companies which control them. No further development of hydro-electric power is probable in the immediate future, as a market for such power is lacking

and is not yet foreseen. Combined development for power and flood control does not appear to be economically justified at either the present or future; but when the potential demand for additional power materializes, supplemental operation of simple flood-control reservoirs by the method of retention of a fractional part of the total flood-storage capacity in other than peak-flood seasons, will permit the conversion of 39,000,000 kilowatt-hours of secondary to primary energy annually at existing downstream plants by means of the Rumford Reservoir alone, or the conversion of 46,000,000 kilowatt-hours of secondary to primary energy annually at existing downstream plants by means of the Rumford, Dixfield and Buckfield Reservoirs in combination. Allocating costs to power and flood control in proportion to the annual benefits (based on existing conditions) tabulated in Paragraph 110, the share of total first cost which should be borne by the power beneficiaries is $4,208,000 for the Rumford Reservoir alone and $5,499,000 for the Rumford, Dixfield and Buckfield Reservoir combination. The annual fixed charges would correspond to 6.1 mils per kilowatt-hour for primary energy at the switchboard in the case of the Rumford development alone, and 6.7 mils per kilowatt-hour in the case of the Rumford, Dixfield and Buckfield combination.

120. Flood Control. - The only practicable method of general flood control in this basin is by means of reservoirs. The plan for four flood-control reservoirs presented in this report is physically but not economically feasible at the present time. In preparation for the time when further development of the basin may warrant construction of these reservoirs, the sites should be reserved and development therein controlled to insure their availability at reasonable cost. The method of operating simple flood-control storage reservoirs to obtain incidental power benefits in the off-flood-peak season, as outlined in Paragraph 119, affords possibilities for economical flood-control development at some future date when the local power demand increases sufficiently to absorb the primary energy generated and thus warrants financial participation by the power interests in proportion to the power benefits

conferred. According to this plan of financing, the Federal and State Governments would be able to obtain, in the case of the Rumford Reservoir taken alone, 295,000 acre-feet of flood-control storage at a cost of $23.60 per acre-foot, or $6,954,000; or, in the case of the Rumford, Dixfield and Buckfield Reservoirs in combination, 396,300 acre-feet of flood-control storage at a cost of $21.70 per acre-foot, or $8,602,000, all based on present estimated costs. The addition of the Oxford Reservoir to the latter group would, as noted in Paragraph 111, result in development far beyond the point of diminishing economic returns and consequently its inclusion in the above plan would not be warranted.

RECOMMENDATIONS

121. It is recommended that the State of Maine or other affected local interests be encouraged to reserve the Rumford, Dixfield and Buckfield project reservoir sites as state or local parks or forests, and control future development within these areas so that they may be available at reasonable cost for flood control either when the portion of the lower valley subject to flood damage will have been developed sufficiently to warrant construction on the basis of flood control alone, or when the need for additional sources of primary electrical energy warrants construction of simple flood-control reservoirs operated to retain a portion of the total flood-control storage in off-flood-peak seasons so as to be available for priming out secondary energy at downstream plants and thus justify financial participation by the power interests and the Federal and State Governments in proportion to the respective benefits to power and to flood control.

122. It is also recommended that, as a condition precedent to future adoption of such a project, the State of Maine enact legislation to control any development on the river which, by obstructing or otherwise reducing the flood-channel capacity, may operate to increase flood heights and damages.

123. It is further recommended that the flood-warning service of the United States Weather Bureau be extended to all portions of the basin

that contribute to flood flows, and amplified by the inclusion of estimates by trained observers of the amount of snow cover and its water equivalent, in order that improved forecasts and adequate flood warnings may be provided.

A. K. B. Lyman
Lt. Col., Corps of Engineers
District Engineer

APPENDICES

APPENDIX A. Reports by Agencies other than United States Engineer Department.

APPENDIX B. Peak Discharges of more than 6,000 Cubic Feet per Second at Rumford, Maine (Average for 1 day).

APPENDIX C. Notes on Accuracy of Gaging Stations.

APPENDIX D. Data Pertaining to Project Reservoirs.

APPENDIX E. Effect of Project Reservoirs upon a Flood Similar to that of March, 1936.

APPENDIX F. Local Flood Protection.

APPENDIX G. Estimated Costs of Project Flood Control Plans.

LIST OF FIGURES ACCOMPANYING REPORT ON ANDROSCOGGIN RIVER

LIST OF FIGURES ACCOMPANYING REPORT ON ANDROSCOGGIN RIVER
(Continued)

APPENDIX A. REPORTS BY OTHER AGENCIES - FEDERAL AND STATE ORGANIZATIONS, TECHNICAL SOCIETIES, INDIVIDUALS, ETC.

124. The following is a list of reports and publications by other than departmental agencies, referred to in Paragraph 3.

<u>United States Geological Survey</u>

The New England Flood of 1927.

Water Supply Papers - Contain data on gaging stations and stream flow.

<u>United States Weather Bureau</u>

Climatological Data. Monthly and annual publications of meteorological information.

<u>National Resources Board</u>

Inventory of the Water Resources of the North Atlantic Drainage Area, by H. K. Barrows, 1935.

<u>Maine Water Power Commission</u>

Annual Reports. Contain prior to 1925, data upon water storage, power sites and development, stream flow, hydrology and topographic mapping in the State of Maine.

<u>Maine Public Utilities Commission</u>

Biennial Reports. Contain, since 1925, data on hydrology, water power, water resources, power rates, topographic mapping, etc., in the State of Maine, formerly published by the Maine Water Power Commission.

Special Water Power Investigation, 1918. Deals with developments on the principal Maine rivers of power, existing and potential, together with means of increasing the latter by the construction of storage reservoirs.

<u>Maine Development Commission</u>

Water Power Resources of the State of Maine, 1929. Contain much data upon existing power-generating facilities, potential development, stream flow, storage, power costs, etc.

Maine Rivers and their Protection from Possible Flood Hazards, 1929. Analyzes very completely the possible maximum storms to be expected and their effects upon river stages.

<u>Maine State Planning Board</u>

Report for 1934 - 1935. Includes data on climatology, water resources, power developments, rates, etc.

<u>New Hampshire Power Survey Committee.</u>

New Hampshire Power, 1926. Discusses the power resources of the state, existing and potential, and includes lists of developed water powers, stream gaging stations, and storage reservoirs.

<u>New Hampshire Water Resources Board</u>

Extent and Magnitude of the March, 1936, Flood in New Hampshire. Contains tables of flood discharges at various points in Saco and other river basins.

<u>New England Water Works Association</u>

Journal. Issues of September, 1915, September, 1921, and June, 1926, contain papers by X. H. Goodnough giving summaries of rainfall in New England from earliest records to 1935.

Journal. Issues of June, 1928, and March, 1930, contain papers by the same author, dealing with rainfall during the New England storm of November 3 - 4, 1927.

Journal. Issue of March, 1930. Symposium on Rainfall of New England.

<u>Boston Society of Civil Engineers</u>

Report of Committee on Floods. Published in Journal of the Society, issue of September, 1930. Deals with floods in New England.

American Society of Civil Engineers

The 1936 Flood in New England. Paper by William F. Uhl, presented before the October, 1936, meeting of the Society. Deals with causes of the flood, stages and discharges, economics of flood-control works, and behavior of storage reservoirs during the flood. Discussion by Captain Hugh J. Casey, Corps of Engineers.

APPENDIX B. DISCHARGES OF MORE THAN 6000 CUBIC FEET PER SECOND, AVERAGE FOR ONE DAY

ANDROSCOGGIN RIVER AT RUMFORD, MAINE

125. The following list of discharges of over 6000 cubic feet per second (average for one day) on the Androscoggin River at Rumford, Maine, formed the basis of the probability computations from which the expectancy of floods and the resulting damages were calculated. Figures in parentheses following flood discharge indicate relative magnitude of flood.

Date	Discharge Sec.-Ft.	Date	Discharge Sec.-Ft.
1892		1894 (Cont'd.)	
May 24	11,700	May 26	11,630
June 22	11,200	May 30	19,230
June 29	19,900	June 19	6,170
July 5	17,500	November 1	7,380
August 26	8,500		
November 17	24,500	1895	
		April 9	15,030
1893		April 15	55,230(2)
April 15	8,050	May 13	17,070
April 29	7,050	May 28	8,730
May 5	25,460	October 1	6,380
May 18	38,060(5)	November 27	15,650
June 12	9,700	December 28	12,420
June 26	8,400		
August 30	12,300	1896	
October 25	13,000	January 1	21,540
		March 2	39,010(4)
1894		April 17	27,390
March 21	7,090	1897	
April 21	22,230	April 17	11,435
May 21	6,170	April 26	18,990

Date	Discharge Sec.-Ft.	Date	Discharge Sec.-Ft.
1897 (Cont'd.)		1901	
May 4	19,270	April 9	17,120
May 14	19,220	April 15	14,280
May 28	12,430	April 22	32,650(8)
June 6	8,200	May 12	16,510
June 11	14,760	May 20	16,810
June 15	22,910	June 4	7,420
1898		December 15	27,780
March 15	7,500	1902	
March 21	9,620	January 23	8,150
March 31	10,860	March 3	17,240
April 18	13,270	March 18	11,690
April 25	16,750	March 23	12,850
May 13	15,570	March 30	18,490
June 9	6,200	April 10	9,980
June 15	7,980	April 18	6,430
October 27	11,530	April 24	10,270
1899		May 1	14,580
April 27	23,290	May 28	17,540
May 2	24,080	June 9	9,200
1900		June 17	7,380
February 14	6,010	June 27	6,990
April 20	22,020	October 29	8,340
May 4	17,090	1903	
May 16	13,420	March 12	10,660
May 20	24,530	March 21	19,040
June 4	7,460	March 25	19,760
November 10	12,060	April 10	9,230

Date	Discharge Sec.-Ft.	Date	Discharge Sec.-Ft.
1903 (Cont'd.)		1906 (Cont'd.)	
May 4	6,350	May 28	15,440
June 13	26,790	June 3	8,480
June 22	6,390	June 7	9,160
1904		June 18	6,390
April 11	18,000	June 24	7,240
April 30	28,000(10)	1907	
May 10	19,330	March 31	7,220
May 20	19,860	April 24	12,040
October 22	13,050	May 1	23,830
December 10	8,280	May 10	10,780
1905		May 17	12,090
March 31	12,390	July 1	6,760
April 7	6,220	September 30	7,170
April 22	9,090	October 9	6,210
May 7	8,650	October 29	14,020
June 27	6,540	November 3	23,020
July 31	17,520	November 7	22,770
September 4	6,250	December 11	14,930
1906		1908	
January 24	7,750	March 29	9,900
April 16	11,510	April 7	6,430
April 22	10,960	April 16	6,780
May 1	8,280	May 1	18,700
May 10	11,310	May 11	10,820
May 19	9,480	May 31	11,940

Date	Discharge Sec.-Ft.	Date	Discharge Sec.-Ft.
<u>1909</u>		<u>1912</u> (Cont'd.)	
April 8	10,240	May 14	7,140
April 15	23,620	June 1	9,150
April 20	20,040	October 25	12,840
May 11	14,640	November 8	9,170
May 17	16,090	<u>1913</u>	
May 29	9,510	March 16	7,250
June 3	7,610	March 22	15,900
September 29	7,870	March 26	19,100
<u>1910</u>		April 1	14,700
January 23	14,220	April 6	8,720
March 26	9,060	April 16	9,300
April 1	10,580	April 20	8,480
April 7	12,800	April 26	10,700
April 23	11,240	May 25	7,450
April 27	14,250	May 30	9,080
May 4	6,860	September 23	8,490
<u>1911</u>		October 3	7,180
April 16	7,470	October 21	13,800
May 2	15,000	October 27	6,400
May 8	6,980	November 10	22,000
<u>1912</u>		<u>1914</u>	
April 8	11,200	April 10	6,010
April 17	17,000	April 21	23,900
April 23	12,800	April 30	10,100
April 28	8,580	May 6	11,000
May 10	6,320	May 10	16,100

Date	Discharge Sec.-Ft.	Date	Discharge Sec.-Ft.
1915		1917 (Cont'd.)	
February 26	13,900	June 12	21,700
April 12	11,800	June 18	30,300(9)
April 26	7,720	October 31	15,210
May 1	10,300	1918	
July 9	17,100	April 3	12,430
1916		April 8	6,510
February 27	7,480	April 18	7,060
April 2	8,900	April 24	7,290
April 19	9,150	May 1	11,180
April 24	14,900	May 14	6,020
May 2	7,230	October 7	8,600
May 18	19,500	October 31	8,300
May 31	6,230	1919	
June 10	15,900	March 22	6,780
June 19	12,500	March 29	12,800
June 28	7,220	April 8	6,480
July 5	7,850	April 13	11,200
August 10	8,130	May 6	6,460
September 16	6,020	May 19	7,920
December 1	8,950	May 23	14,600
1917		November 1	7,300
April 7	6,440	November 13	6,600
April 23	13,500	1920	
April 30	7,960	March 28	10,400
May 15	6,100	April 6	8,120
May 21	7,430	April 14	18,600
May 30	6,030		

Date	Discharge Sec.-Ft.	Date	Discharge Sec.-Ft.
1920 (Cont'd.)		1922 (Cont'd.)	
April 24	13,600	June 5	6,190
April 29	9,770	June 19	16,000
May 10	10,600	June 23	17,200
May 22	8,130	June 30	16,000
May 27	6,740	1923	
June 7	6,250	April 9	8,580
October 1	12,300	April 22	18,500
December 6	11,300	April 30	33,800(7)
December 15	12,600	May 10	8,850
1921		May 22	7,280
March 10	6,910	November 25	10,000
March 17	6,450	December 1	6,860
March 22	16,800	December 7	6,670
March 29	13,800	1924	
April 6	7,550	April 15	6,290
April 10	8,170	April 23	6,120
April 18	8,440		
April 25	8,450	May 1	19,900
November 20	6,770	May 5	13,200
1922		May 13	17,200
April 12	21,900	September 11	26,200
April 19	18,100	October 1	11,400
April 27	6,440	November 24	23,400
May 1	6,070	1925	
May 6	12,500	February 13	14,200
May 20	11,300	March 29	21,400

Date	Discharge Sec.-Ft.	Date	Discharge Sec.-Ft.
1925 (Cont'd.)		1928 (Cont'd.)	
April 11	6,380	May 6	10,400
April 16	6,460	May 21	11,400
April 27	7,770	May 25	19,000
May 4	7,580	June 7	6,920
November 9	7,470	1929	
November 17	13,000	March 24	6,160
December 6	9,390	April 9	14,300
1926		April 18	7,820
April 26	12,800	April 29	14,700
May 4	20,400	May 4	22,000
May 17	6,840	May 20	11,100
June 16	10,800	1930	
November 19	8,950	April 8	20,600
1927		April 14	13,800
March 19	7,400	April 20	9,440
April 23	11,600	May 3	12,600
May 16	6,470	May 27	14,600
October 14	8,860	June 11	12,500
October 20	10,300	1931	
November 5	39,100(3)	April 12	12,200
November 18	9,170	April 22	10,400
December 1	6,970	April 27	8,000
December 9	11,000	May 15	6,190
1928		May 24	14,100
March 28	6,780	June 10	20,200
April 8	21,600		

Date	Discharge Sec.-Ft.	Date	Discharge Sec.-Ft.
1932		1934 (Cont'd.)	
January 16	8,610	April 26	18,500
April 2	6,440	May 4	14,300
April 9	9,380	September 18	7,130
April 13	18,700	December 2	8,680
April 23	10,700	1935	
April 27	6,580	January 11	6,830
May 2	12,400	April 16	7,990
May 22	6,200	April 29	19,000
May 29	6,090	May 8	10,000
September 17	24,000	June 1	6,370
October 7	13,200	June 11	12,800
November 2	11,100	June 20	12,700
November 20	14,100	November 29	7,800
1933		1936	
April 8	7,890	March 13	35,600(6)
April 19	24,500	March 19	68,300(1)
April 26	16,300	April 7	17,900
May 4	22,200	May 4	18,800
May 14	11,400	May 15	13,200
May 20	9,460		
June 2	7,000		
August 25	9,160		
1934			
April 3	7,230		
April 13	23,900		
April 20	21,500		

APPENDIX C. ACCURACY OF GAGING STATIONS

126. The United States Geological Survey comments upon the accuracy of these stations as follows:

a. Androscoggin River at Errol Dam, New Hampshire. Discharge computed from flow through 14 gates.

b. Androscoggin River at Berlin, New Hampshire, Discharge determined from flow through wheels and flume.

c. Androscoggin River near Gorham, New Hampshire. Records excellent. Regulation from controlled storage in Rangeley Lakes.

d. Androscoggin River at Shelburne, New Hampshire. A good rating curve has been developed for medium and high stages. At low water, results are approximate. Discharge is affected by ice in winter.

e. Androscoggin River at Rumford, Maine. Discharge computed from flow over dam and through turbine wheels. Regulation from Rangeley Lakes.

f. Androscoggin River at Dixfield, Maine. Rating curve is fairly good for low and medium stages. Discharge is affected by ice in winter.

g. Androscoggin River at Gulf Island Dam, Maine. Records furnished by Central Maine Power Co., Augusta, Maine.

h. Androscoggin River near Auburn, Maine. Records good. Regulation from Rangeley Lakes.

i. Magalloway River at Aziscohos Dam. Discharge computed from eight openings.

j. Swift River at Roxbury, Maine. Records excellent except during period of ice cover, when they are fair.

k. Little Androscoggin River at South Paris, Maine. Records excellent except for discharges below 15 c.f.s.

APPENDIX D. DATA PERTAINING TO PROJECT RESERVOIRS

127. The methods employed in determining spillway-crest elevation, the size and number of conduits and gates and length of spillway crest are briefly described below. A detailed description and discussion of these methods are contained in the 1936 flood control report on the Merrimack River.

128. <u>Spillway-Crest Elevation</u>. - Selection of the proper spillway-crest elevation is largely a question of economics and of minimum storage requirements. Where basic operation of reservoirs as retarding basins appeared most desirable, a minimum storage was established equivalent to 5 inches of run-off over the net drainage area where obtainable within economic limits. The upper limit of storage was then fixed at an elevation affording at least 5 inches of run-off and avoiding in so far as possible extensive flooding of towns, railroads, highways, and other works in the reservoir area.

129. Size and Number of Conduits and Gates. - With the spillway-crest elevation established, the theoretical conduit area may be determined by routing the outlet design flood through the reservoir. Routing curves are prepared to facilitate the solution of the basic equation:

$$\text{Inflow} = \text{Outflow} + \text{Storage}$$

Incremental inflows in acre-feet taken at one-half day intervals are then routed through openings of different sizes from which a curve of "Water-Surface Elevation versus Area of Outlet" may be plotted. From this curve it is then possible to select the theoretical outlet area corresponding to the established spillway elevation. Natural and modified hydrographs at the proposed reservoirs for the outlet design flood are shown in Figures 38, 39, 40 and 41.

130. Under the comparatively low operating head conditions which exist at the proposed dams, considerations of economy and of simplicity of operation favor a sliding type of gate. The size of gates is limited by practical considerations, especially with regard to standardization

and to provision of adequate area for safe passage of ice and debris.

131. Although it is intended to operate all reservoirs primarily as retarding basins, gates are to be provided of such capacity as to discharge the outlet design flood while the water surface rises to the spillway crest. It is not considered necessary to provide gate area in excess of conduit area where, for conduit lengths of 50 feet or less, only one gate per conduit is provided. For longer conduits it is intended to provide several smaller entrance ports which must necessarily be of greater total area than the main conduit in order to compensate for increased frictional losses. Each entrance port is to be equipped with a gate of approximately the same area and shape as the port itself.

132. Auxiliary Gates and Conduits. - It has been considered advisable to provide additional conduit area (equipped with gates) equal to that actually required for retarding reservoir operation alone, in order: (1) to facilitate passage of annual floods during the construction period, (2) to provide for more rapid emptying of reservoirs after flood danger below has passed, (3) to provide for a maximum future possible river regulation, and (4) to insure supplemental gates and conduit capacity in event some of the gates are damaged and inoperative at the time of a flood.

133. Length of Spillway Crest. - The length of spillway crest is determined by routing the spillway design flood through several different lengths of spillway crest, assuming all gates closed and water surface at spillway-crest elevation at the beginning of the flood. A curve of "Surcharge on Spillway Crest versus Length of Spillway" is then plotted (see Figure 42), from which it is possible to select a spillway-crest length consistent with economic considerations, but not less than that corresponding to a surcharge of 10 feet. A minimum freeboard of 5 feet above the surcharge selected is provided. Initial calculations are based on an Ogee type of spillway. For a channel type of spillway the width may be calculated by selection of proper coefficients.

134. Under actual operating conditions, it is possible during rare excessive floods, by opening all gates, including the auxiliary gates, to reduce the calculated surcharge by a considerable amount and thus prevent extensive flooding in the reservoir above the spillway-crest elevation. Such floods would normally overtop the spillway. Stage-frequency curves, showing the levels to which the reservoirs would be filled by floods of varying frequencies, are attached as Figures 43 to 46, inclusive. These curves were computed for reservoirs operated as retarding basins, with outlets (except auxiliary gates) always open.

135. Length and elevation of spillway crest, size and number of conduits and gates, and other pertinent data as determined for the proposed reservoirs are given in Table A following:

TABLE A

ANDROSCOGGIN DRAINAGE BASIN

DATA PERTAINING TO DAMS AND APPURTENANCES

Item No.	Item		Name of Dam			
			Rumford	Dixfield	Buckfield	Oxford
1.	Drainage area,	sq. mi.	965(net)	125	156	231
2.	Drainage area under control, per cent of net drainage area,*	2,375 sq. mi.	40.6	5.3	6.6	9.7
3.	Ave. elev. bed of river at dam site,	ft. above M.S.L.	575	415	300	275
4.	Elevation of spillway crest,	ft. " "	655	450	345	325
5.	Length of spillway crest,	ft.	750	83	***** 130	165
6.	Surcharge on spillway crest,**	ft.	10	10	10	8
7.	Elevation top of dam,	ft. above M.S.L.	670	465	360	338
8.	Channel capacity at dam site,***	c.f.s.	26,430	1,700	3,360	3,480
9.	Theoretical outlet area, At - based on 100-year flood filling to spillway crest,	sq. ft.	300	45	40	63
10.	Total no. of outlet conduits		2	4	1	4
11.	No. of gates per conduit		7	1	4	1
12.	Size of gates,	ft. x ft.	10x5.5	7x3.75	7x3.75	7x4.5
13.	Length of each conduit,	ft.	1,250	50	200	25
14.	Sectional area of each conduit,	sq. ft.	380	26.25	94.75	31.5
15.	Invert elevation of conduit,	ft. above M.S.L.	585	415	297	273
16.	No. of gates closed, water surface at spillway crest,		7	2	2	2
17.	Storage capacity to spillway crest, acre-feet,		295,000	40,300	61,000	92,000
18.	Storage capacity to spillway crest, inches of run-off,		5.7	6.0	7.3	7.5
19.	Area in basin at elevation of spillway crest,	acres	15,200	2,030	4,050	6,100
20.	Outflow through conduits with water level at spillway crest, ****	c.f.s.	16,400	1,980	1,920	3,380
21.	Velocity of outflow with water level at spillway crest,	ft. per sec.	43.2	37.7	20.3	53.6

* Net drainage area is the total area above the dam less the area controlled by upstream dams.
** Produced by spillway design flood with water surface at spillway-crest elevation and outlets considered closed at beginning of flood.
*** Capacity required to carry probable annual flood.
**** Outflow computed with the number of gates closed that are indicated under item No. 16.
***** Width of channel spillway.

Drainage Area
3,470 sq. mi. gross
1,095 sq. mi. above Errol Dam owned by Union Water Power Co. of Lewiston, Maine (Storage regularly drawn down in anticipation of spring run-off)
2,375 sq. mi. net
1,477 sq. mi. under control by proposed reservoirs - 62.2% of Net Drainage Area.

APPENDIX E. EFFECT OF PROPOSED RESERVOIRS UPON A FLOOD SIMILAR TO THAT OF MARCH, 1936.

136. The following notes show the effects at various locations upon a flood similar to that of March, 1936, of the Rumford, Dixfield, Buckfield and Oxford Reservoirs in combination.

a. <u>At Rumford, Maine, on main stem of Androscoggin River:</u>

A maximum stage of 612 feet (U.S.G.S. datum) was recorded on the gage about midnight of March 19. The drainage area above the gage is 2090 square miles, of which 1095 square miles may be considered as under fullcontrol as a result of operation of Errol Dam, owned by the Union Water Power Company of Lewiston, Maine. The proposed Rumford Reservoir is located about 6 miles above the gage and controls a drainage area of 965 square miles, or 46 per cent of the entire area and 97 per cent of the net area above the gage. For a flood similar to that of March, 1936, Rumford Reservoir would have reduced the flow at the gage from 74,000 cubic feet per second to 36,300 cubic feet per second, equivalent to a reduction in gage height of approximately 4.6 feet. The effect of the reservoir on the gage hydrograph for the entire flood peak is shown on Figure 47. Figure 48 shows the natural and modified hydrograph at Rumford Dam for a flood similar to that of March, 1936. Referring to this figure, it will be noted that a flood similar to that of March, 1936, would have discharged over the spillway. A surcharge on the spillway crest of 3.8 feet would have resulted, which could have been materially reduced by opening the auxiliary gates described in Paragraph 132, APPENDIX D.

b. <u>At Livermore Falls, Maine, on main stem of Androscoggin River:</u>

A maximum stage of 11.1 feet (local datum) was recorded on the gage about 8:00 P.M. of March 19. The net drainage area above the gage is 1356 square miles (assuming area above Errol Dam under control). Rumford and Dixfield Reservoirs are located about 33 miles and 22 miles, respectively, above the gage. The two reservoirs in combination control a drainage area of 1090 square miles or 80.5 per cent of the net area above the gage. For a flood similar to that of March, 1936, they would have reduced the flow at the gage from 94,000 cubic feet per second to 49,500 cubic feet per second, equivalent to a reduction in gage height of 2.5 feet. The effect of the two reservoirs in combination for the entire flood peak at Livermore Falls is shown on Figure 49. Figure 50 shows the natural and modified hydrograph at Dixfield Dam for a flood similar to that of March, 1936. Referring to this figure, it will be noted that a flood similar to that of March, 1936, would have discharged over the spillway. A surcharge on the spillway crest of 2.0 feet would have resulted, which could have been materially reduced by opening the auxiliary gates as described in Paragraph 134, APPENDIX D.

c. <u>At Lewiston, Maine, on main stem of Androscoggin River; above the mouth of the Little Androscoggin River:</u> A maximum stage of 264.5 feet (U.S.G.S. datum) was recorded on the gage about 4:00 A.M. of March 20. The drainage area above the gage is 1752 square miles net. The proposed Rumford, Dixfield, and Buckfield Reservoirs are located about 64.5, 54 and 23 miles, respectively, above the gage, and control a combined drainage area of 1246 square miles or 71.1 per cent of the net area above the gage. For a flood similar to that of March, 1936, the three reservoirs in combination would have reduced the flow at the gage from 118,000 cubic feet per second to 65,000 cubic feet per second, equivalent to a reduction in gage height of approximately 5.0 feet. The effect of the reservoirs on the gage hydrograph for the entire flood peak is shown on Figure 51. Figure 52 shows the natural and modified hydrograph at Buckfield

Dam for a flood similar to that of March, 1936.

d. <u>Little Androscoggin River at Auburn, Maine</u>: A maximum stage of 141.9 feet (U.S.G.S. datum) was recorded on the gage about 6:00 A.M. of March 20. The drainage area above the gage is 380 square miles. Oxford Reservoir is located about 15 miles above the gage and controls a drainage area of 231 square miles or 60.9 per cent of the entire area above the gage. For a flood similar to that of March, 1936, Oxford Reservoir would have reduced the flow at the gage from 23,700 cubic feet per second to 12,700 cubic feet per second, equivalent to a reduction in gage height of 15.2 feet. The effect of the reservoir for the entire flood peak at the gage is shown on Figure 53. Figure 54 shows the natural and modified hydrograph at Oxford Dam for a flood similar to that of March, 1936. Referring to this figure, it will be noted that a flood similar to that of March, 1936, would have discharged over the spillway. A surcharge on the spillway crest of 3.0 feet would have resulted, which could have been materially reduced by opening the auxiliary gates described in Paragraph 134, APPENDIX D.

e. <u>At Lisbon Falls, Maine, on main stem of Androscoggin River</u>: A maximum stage of approximately 12.3 feet (local datum) was recorded on the gage about 8:00 A.M. of March 20. The drainage area above the gage is 2305 square miles net. The proposed Rumford, Dixfield, Buckfield and Oxford Reservoirs are located about 79, 68.5, 39 and 30 miles, respectively above the gage, and control a combined drainage area of 1477 square miles or 64.1 per cent of the net drainage area above the gage. For a flood similar to that of March, 1936, the four reservoirs in combination would have reduced the flow at the gage from approximately 155,000 cubic feet per second to 98,500 cubic feet per second, equivalent to a reduction in gage height of approximately 2.8 feet. The effect of the reservoirs on the gage hydrograph for the entire flood peak is shown on Figure 55.

137. Conditions at the proposed dams and approximate reductions in stage and discharge for a flood similar to that of March, 1936, are given in Tables B, C, and D. Figures 36 and 37 show the approximate natural and modified profile of the March, 1936, flood on the Androscoggin River from the sites of the dams to the mouth of the river.

138. The following notes show the effects upon a flood similar to that of March, 1936, at Rumford Reservoir alone:

<u>a</u>. Rumford Reservoir would have reduced the flow at the gage from 74,000 cubic feet per second to 36,300 cubic feet per second, equivalent to a reduction in gage height of approximately 4.6 feet.

<u>b</u>. <u>At Livermore Falls, Maine, on main stem of Androscoggin River:</u> Rumford Reservoir would have reduced the flow from 94,000 cubic feet per second to 57,500 cubic feet per second, equivalent to a reduction in gage height of approximately 2.1 feet.

<u>c</u>. <u>At Lewiston, Maine, on main stem of Androscoggin River; above the mouth of the Little Androscoggin River:</u> Rumford Reservoir would have reduced the flow from 118,000 cubic feet per second to 83,800 cubic feet per second, equivalent to a reduction in gage height of 3.2 feet.

<u>d</u>. <u>Little Androscoggin River at Auburn, Maine</u>: Rumford Reservoir is located on the main stem of the Androscoggin River and, therefore, will not affect the flow in this or other tributaries except near their mouths.

<u>e</u>. <u>At Lisbon Falls, Maine, on main stem of Androscoggin River</u>: Rumford Reservoir would have reduced the flow from 155,000 cubic feet per second to 123,000 cubic feet per second, equivalent to a reduction in gage height of 1.6 feet.

139. The following notes show the effects upon a flood similar to that of March, 1936, at Rumford, Dixfield and Buckfield Reservoirs in combination.

<u>a</u>. At Rumford, Livermore Falls, Lewiston and Auburn, all in Maine, the effects are the same as for the combination of four reservoirs, including Oxford.

b. At Lisbon Falls, Maine, the three reservoirs would have reduced the flow from 155,000 cubic feet per second to 113,000 cubic feet per second, equivalent to a reduction in gage height of 2.0 feet.

TABLE B

CONDITIONS AT PROJECT DAMS FOR

A FLOOD SIMILAR TO THAT OF MARCH, 1936

No.	Item		Name of Dam			
			Rumford	Dixfield	Buckfield	Oxford
1.	Elevation of spillway crest,	feet above mean sea level	655	450	345	325
2.	Max. rate of inflow,	cubic feet per second	74,000	10,800	10,300	13,800
3.	Max. water-surface elevation attained in reservoir,	feet above mean sea level	658.8	452.0	345.0	328.0
4.	Area flooded in reservoir,	acres	16,800	2,600	4,050	11,200
5.	Surcharge on spillway crest,	feet	3.8	2.0	0	3.0
6.	Max. rate of outflow corresponding to spillway surcharge,	cubic feet per second	19,400	860	0	2,650
7.	Max. rate of outflow through conduits,	cubic feet per second	16,800	2,040	1,920	3,500
8.	Combined max. rate of outflow, spillway and conduits,	cubic feet per second	36,200	2,900	1,920	6,150
9.	Approximate time to empty reservoir, days*		27**	16	24**	18

* Auxiliary conduits, controlled by gates, are provided in all retarding reservoirs to expedite emptying after maximum reservoir stage has been reached. Discharge through controlled conduits will be so regulated as to maintain a total reservoir discharge not exceeding that from the uncontrolled conduits five days after maximum reservoir stage.

** Time may be reduced to approximately 20 days if all gates are opened wide after flood danger below has passed.

TABLE C

ANDROSCOGGIN

CONDITIONS AT DAMS FOR OUTLET DESIGN FLOOD
(100-Year Flood at Dam Site)

No.	Item		Name of Dam: Rumford	Dixfield	Buckfield	Oxford
1.	Elevation of spillway crest,	feet above mean sea level	655	450	345	325
2.	Max. rate of inflow,	cubic feet per second	76,500	7,900	13,200	14,800
3.	Max. water-surface elevation attained in reservoir,	feet above mean sea level	655	450	345	325
4.	Area flooded in reservoir,	acres	15,200	2,030	4,050	6,100
5.	Max. rate of outflow through conduits,	cubic feet per second	16,400	1,980	1,920	3,390
6.	Approximate time to empty reservoir, days* (assuming base flow of 1 c.f.s. per sq. mi.)		12	13	19	15

* Auxiliary conduits, controlled by gates, are provided in all retarding reservoirs to expedite emptying after maximum reservoir stage has been reached. Discharge through controlled conduits will be so regulated as to maintain a total reservoir discharge not exceeding that from the uncontrolled conduits five days after maximum reservoir stage.

TABLE D

APPROXIMATE REDUCTIONS IN STAGE AND DISCHARGE AT SEVERAL STATIONS
FOR A FLOOD SIMILAR TO THAT OF MARCH, 1936

Station	Drainage Area above Sq. Mi.	Reservoirs above Station	Drainage Area under Control		Discharge c.f.s.			Stage in Feet		Net Reduction
			Sq. Mi.	Per Cent	Natural Flow	Modified Flow	Per Cent Reduction	Recorded	Modified	
Rumford, Me. (On main stem of Androscoggin River)	995*	Rumford	965	97	74,000	36,300	50.9	612**	607.4**	4.6
Livermore Falls, Me. (On main stem of Androscoggin River)	1356*	Rumford	965	70.7	94,000	57,500	38.8	11.1***	9.0***	2.1
		Rumford and Dixfield	1090	80.5	94,000	49,500	47.3	11.1***	8.6***	2.5
Lewiston, Me. (On main stem of Androscoggin River)	1752*	Rumford	965	55.1	118,000	83,800	29.0	264.5**	261.3**	3.2
		Rumford, Dixfield and Buckfield	1246	71.1	118,000	65,000	44.9	264.5**	259.5**	5.0
Auburn, Me. (At mouth of Little Androscoggin River)	380	Oxford	231	60.9	23,700	12,700	46.4	141.9**	126.7**	15.2
Lisbon Falls, Me. (On main stem of Androscoggin River)	2305*	Rumford	965	41.9	155,000	123,000	20.7	12.3***	10.7***	1.6
		Rumford, Dixfield, Buckfield and Oxford	1477	64.1	155,000	98,500	36.5	12.3***	9.5***	2.8
		Rumford, Dixfield and Buckfield	1246	54.1	155,000	113,000	27.1	12.3***	10.3***	2.0

* Net drainage area (drainage area above Errol Dam (1095 sq. mi.) not included).
** U.S.G.S. Datum
*** Local Datum

APPENDIX F. LOCAL FLOOD PROTECTION

139. Purpose. - The flood-control studies for the Androscoggin basin indicated that general flood protection throughout the valley could best be afforded by reservoir control. However, it has been shown that the construction of flood-control reservoirs is not economically justified at the present time and it is considered desirable, therefore, to effect some measure of flood protection by other means wherever it can be accomplished and economically justified. The purpose of this appendix, therefore, is to analyze and determine the feasibility of local flood protection at various damage centers by means other than reservoir control.

140. Scope. - Preliminary estimates of the cost of affording such protection have been made for certain damage centers, based chiefly on data available on United States Geological Survey topographic maps and the 1936 flood profiles as determined by this office. Detailed surveys of the particular areas studied have not been available nor have any special surveys been made. The damage centers studied include Berlin, New Hampshire, both on the Androscoggin and Dead Rivers, and Virginia, Rumford, Mexico, Chisholm, Livermore Falls, Lewiston, Auburn, Lisbon Falls, The Pejepscot Paper Company, Brunswick and Topsham, all in Maine. (See Fig. 2.)

141. Procedure. - The general procedure followed was to determine the annual flood damage at the respective damage centers. The cost of providing dikes, walls, or channel improvement necessary to eliminate all flood damage in these areas was then determined. Because of the lack of detailed surveys and other information for specific localities, a complete evaluation of all the factors to be considered was not possible. Therefore, unit costs of $1.50 per cubic yard for earth dikes and from $150 to $250 per linear foot for concrete walls were selected for these preliminary estimates and consideration was given to the local problems likely to be encountered, such as cofferdamming, underpinning, etc. Annual carrying charges were computed using a 50-year amortization period and interest rates of 4 per cent and 5 per cent on Federal and local costs, respectively. The annual costs and benefits are summarized in the following table:

SUMMARY OF COSTS AND BENEFITS - LOCAL FLOOD PROTECTION

Locality	Federal Invest-ment	Non-Federal Invest-ment	Total Invest-ment	Annual Federal Carrying Charge	Annual Non-Federal Carrying Charge	Total Annual Carrying Charge	Total Annual Benefits	Ratio of Benefits to Cost
Berlin, N. H.								
a. Androscoggin R.	$1,318,000	$ 8,000	$1,326,000	$ 61,370	$ 680	$ 62,050	$ 2,300	0.037
b. Dead River	114,800	15,000	129,800	5,350	1,580	6,930	1,000	0.144
Virginia, Me.	674,200	24,000	698,200	31,400	2,540	33,940	5,120	0.151
Rumford, Me.	1,248,000	6,000	1,254,000	68,060	510	68,570	22,470	0.328
Mexico, Me.	328,200	13,500	341,700	15,260	1,650	16,910	10,000	0.590
Chisholm, Me.	226,800	2,000	228,800	10,580	170	10,750	2,340	0.218
Livermore Falls	626,000	4,000	630,000	29,100	340	29,440	7,410	0.250
Lewiston, Me.	2,474,600	10,000	2,484,600	115,200	850	116,050	10,880	0.094
Auburn, Me.	3,240,000	15,000	3,255,000	150,800	1,275	152,075	32,350	0.212
Lisbon Falls, Me.	226,800	5,000	231,800	10,580	430	11,010	4,740	0.430
Pejepscot Paper Co.	1,725,300	4,000	1,729,300	80,300	1,340	81,640	12,000	0.147
Brunswick, Me.	648,000	1,000	649,000	30,100	90	30,190	7,215	0.239
Topsham, Me.	941,600	5,000	946,600	43,900	630	44,530	9,290	0.208

142. From the foregoing table it may be seen that the ratio of annual benefits to annual charges is well under unity for all cases considered. Although the cost estimates are preliminary in character, it is believed that they are sufficiently conservative to establish with reasonable assurance that the economic ratio for all cases will be less than unity even when based on more detailed and accurate information. Therefore, it appears that the provision of substantial local flood protection at any flood-damage center in the Androscoggin Valley is not economically justified at the present time.

143. <u>Alleviation of Flood Hazards by Reconstruction or Removal of Structures</u>. - Some degree of reduction of flood losses may be effected by reconstruction or removal of dams, bridges, and buildings which form artificial obstructions to flood flows. Such improvements generally can be undertaken economically only when the structure has reached the end of its economic or physical life, or when extensive reconstruction is required for some purpose other than for flood control alone. Specific suggestions concerning desirable improvements to be incorporated in plans for reconstruction of existing structures when undertaken for reasons other than for flood control, are listed below by localities. None of these would lessen flood damages to a sufficient degree to warrant their prosecution for flood-control purposes alone.

<u>a</u>. <u>Berlin, N. H.</u> - High-water elevations are controlled by a series of 5 dams in the city. The stream is further obstructed by bends, gorges, ledges, and mill buildings. In addition to the losses caused by the main stream, the Dead River, a small tributary running through the city, caused considerable damage by overflowing its banks.

(1) The Brown Co., whose buildings line both river banks down to Mason Street, is embarking on a program of channel improvement and protection within the limits of its flowage rights. The buildings of the International

Paper Company below the Mason Street bridge are being razed, and if this is properly done, it should improve flow conditions through that reach.

(2) It is suggested that the following additional improvements will be of benefit: Raise the highway bridge above the "Sawmill" dam, raise and lengthen that portion of the Mason Street bridge below the dam spillway; raise and lengthen the railway bridge, and remove the encroachment by the approach fill on the right bank; remove a portion of the high ledge splitting the flood channel below the Mason Street bridge. Consideration should also be given to the possibility of a wall on the right river bank above the "Sawmill" dam, and of raising the right forebay wall of the power canal at Mason Street.

(3) Dead River Improvement. The waterway through the City of Berlin should be improved by deepening and widening the channel when feasible and removing such constrictions as bridges and building encroachments now obstructing the course of the stream. An alternative method of improving flood conditions would be afforded by the construction of a reservoir above the city at the site of the old Brown Company dam. To effect a 50 per cent reduction in the estimated peak flood discharge, 1,500 cubic feet per second, it would be necessary to provide approximately 2,000 acre-feet of storage. In view of the fact that reservoir construction would involve the relocation of approximately 2 miles of main line of the Grand Trunk Railroad, or construction of a sheet pile or concrete dike to protect this railroad, it is believed that a channel improvement will afford the more economical means of flood-control protection.

b. Gorham, N. H. - Local high-water elevation is controlled by the dam. Since the valley here is a wide flat flood plain, it is suggested that the installation of flood gates in the dam will prove effective in reducing damages.

c. Rumford, Me. - High-water elevations in the city are controlled by the Middle dam and the channel conditions in the reaches downstream from it.

(1) Improvements now being undertaken by local interests are as follows: A wall is under construction along the forebay of the upper dam to prevent overflow of the right bank at that point. The upper bridge is being lengthened by adding another span, and a protective wall for the city is under construction on the right bank below the Middle dam. The Oxford Paper Co. is raising the fill on its property at the bend in the stream.

(2) Further improvement in flow conditions might be effected as follows: Cut away ledge under crest of falls above the lower highway bridge, to cause a reduction in flood heights up to the Middle dam; remove ledge in the vicinity of the upper highway bridge to improve the flow under it. Should the wrecked railway bridge at the Oxford Paper Co. be replaced, it should be lengthened and the bar above and below the left abutment cut away. The only possible protection to the village of Mexico would be a wall along the river bank. There is also a possibility that some channel excavation below the bend might be of benefit.

d. Jay, Me. - The stream at this point is divided by two small islands, and is obstructed by three dams and three short highway bridges which have been thrown up between the islands and the shores. The power house in the dam across the left channel takes up a considerable portion of the spillway capacity. Both the dams and the center bridge suffered damage during the last flood. The following improvements are suggested: Set back the abutments and raise all three bridges; provide for flood gates in the dam across the left channel; clear away the ledge between the dam and bridge in the right channel. In reconstructing the bridges consideration should be given to their relocation at a safe distance upstream or downstream from the dams.

e. Livermore Falls and Chisholm, Me. - High-water elevations are controlled by the two dams in the towns. The major portion of the towns being situated well above the flood level, there is not much necessity for improvement. The highway bridge, when rebuilt, could be raised a few feet, and additional channel width obtained by setting back the right abutment.

f. Lewiston and Auburn, Me. - High-water elevations in these cities are controlled by the Union Water Power Company's dam and by natural channel conditions downstream. Appreciable encroachment on the stream has been caused by dumping along both river banks above and below South bridge. There is also some encroachment caused by filling in the left bank between the North bridge and the railway bridge.

(1) The existing South bridge, of which two spans were carried away during the 1936 flood, is being replaced by a new structure having adequate clearance and channel capacity.

(2) Possible improvements, of benefit, to the cities, are suggested as follows: Provide flood gates in the Union Water Power Company's dam; remove the several encroachments on the channel; excavate channel below the North bridge. Consideration should also be given to the possibility of protection walls on both banks of the river. There is also a possibility of lowering flood elevations by removal of the rips below the cities.

g. Lisbon Falls, Me. - High-water elevations here are controlled by the two dams in the town. Since the major portion of the town lies above the flood level, there appears no necessity for extensive improvement. The highway bridge to replace that carried out in the 1936 flood should be given greater clearance; and the channel capacity may be increased by lowering the rock ledge in mid channel, eliminating the present pier on the small island near the left bank.

h. Brunswick, Me. - High-water elevations in the city are controlled by the two dams. There is considerable ledge rock above and below the lower dam, and the mill buildings forming part of the left forebay for the lower dam encroach upon the channel. The continuity of the upper dam is broken by two ledges which restrict the flow. The bridge, 1/4 mile upstream from the upper dam, is a double-decked structure, with the highway bridge underneath and the railway deck above.

(1) It is suggested that the following changes would improve flow conditions through the city: Provide flood gates in the lower dam; remove the ledges and islands above and below the lower dam; increase the spillway capacity of the upper dam by taking out the ledges in it; remove the highway (lower) deck from the bridge upstream, and rebuild it as a separate structure with adequate flood clearance.

(2) Consideration should also be given to the possibility of constructing a wall along the depressed left bank of the river above the lower highway bridge, to prevent overflow into the town of Topsham.

(3) Raise the Maine Central Railroad Bridge to an adequate flood clearance. (This work is now under way.)

At many points along the river, shoals were formed during the March, 1936, floods, particularly at points where natural channel constrictions tend to form ice jams. For example, such ice jams formed during these floods just below two dams owned by the Pejepscot Mills (one 4½ miles above Brunswick, the other the lower dam at Lisbon Falls) and not only increased the amount of damage to the company's property, but resulted in the deposition of material to form shoals which tend to increase damages from future floods. The removal of these channel constrictions and shoals would improve flood conditions locally at numerous points along the river.

APPENDIX G. ESTIMATED COSTS OF PROJECT FLOOD-CONTROL PLANS

Note: Determined in accordance with Section 3 of the Flood Control Act approved June 22, 1936, (Public No. 738, 74th Congress) which requires that local agencies shall, - (1) provide, without cost to the United States, all lands, easements and rights-of-way necessary, except that that part of such costs which exceeds the cost of construction shall be borne equally by the United States and local interests; (2) maintain and operate all the works after completion.

ESTIMATED ANNUAL CARRYING CHARGES

144. Rumford, Dixfield, Buckfield, and Oxford Reservoirs.

a.	Federal Investment	
	(1) Estimated total Federal first cost	$9,338,000
	(2) Interest during construction, 4 per cent of item a(1) for one-half of the estimated construction period	374,000
	(3) Total Federal investment	$9,712,000
b.	Federal Annual Carrying Charges	
	(1) Interest at 4 per cent on item a(3)	$ 388,000
	(2) Amortization of obsolescence and depreciation (see Paragraph 147)	71,000
	(3) Total Federal carrying charges	$ 459,000
c.	Non-Federal Investment	
	(1) Estimated total non-Federal first cost	$8,457,000
	(2) Interest during construction, 5 per cent of item c(1) for one-half of the estimated construction period	423,000
	(3) Total non-Federal investment	$8,880,000
d.	Non-Federal Carrying Charges	
	(1) Interest at 5 per cent on item c(3)	$ 444,000
	(2) Amortization (see Paragraph 147)	42,000
	(3) Estimated cost of maintenance and operation	25,000
	(4) Loss of taxes on lands and property used for reservoir purposes	30,000
	(5) Total non-Federal carrying charges	$ 541,000
e.	Total Carrying Charges (item b plus item d)	$1,000,000

145. Rumford, Dixfield and Buckfield Reservoirs.

a.	Federal Investment	
	(1) Estimated total Federal first cost	$7,491,000
	(2) Interest during construction, 4 per cent of item a(1) for one-half of the estimated construction period	300,000
	(3) Total Federal investment	$7,791,000
b.	Federal Annual Carrying Charges	
	(1) Interest at 4 per cent on item a(3)	$ 312,000
	(2) Amortization of obsolescence and depreciation (see Paragraph 147)	58,000
	(3) Total Federal carrying charges	$ 370,000
c.	Non-Federal Investment	
	(1) Estimated total non-Federal first cost	$6,610,000
	(2) Interest during construction, 5 per cent of item c(1) for one-half of the estimated construction period	330,000
	(3) Total non-Federal investment	$6,940,000
d.	Non-Federal Carrying Charges	
	(1) Interest at 5 per cent on item c(3)	$ 347,000
	(2) Amortization (see Paragraph 147)	33,000
	(3) Estimated cost of maintenance and operation	20,000
	(4) Loss of taxes on lands and property used for reservoir purposes	23,000
	(5) Total non-Federal carrying charges	$ 423,000
e.	Total Carrying Charges (item b plus item d)	$ 793,000

146. Rumford Reservoir.

a. Federal Investment

(1)	Estimated total Federal first cost	$5,581,000
(2)	Interest during construction, 4 per cent of item a(1) for one-half of the estimated construction period	223,000
(3)	Total Federal investment	$5,804,000

b. Federal Annual Carrying Charges

(1)	Interest at 4 per cent on item a(3)	$ 232,000
(2)	Amortization of obsolescence and depreciation (see Paragraph 147)	43,000
(3)	Total Federal carrying charges	$ 275,000

c. Non-Federal Investment

(1)	Estimated total non-Federal first cost	$5,581,000
(2)	Interest during construction, 5 per cent of item c(1) for one-half of the estimated construction period	279,000
(3)	Total non-Federal investment	$5,860,000

d. Non-Federal Carrying Charges

(1)	Interest at 5 per cent on item c(3)	$ 293,000
(2)	Amortization (see Paragraph 147)	28,000
(3)	Estimated cost of maintenance and operation	10,000
(4)	Loss of taxes on lands and property used for reservoir purposes	20,000
(5)	Total non-Federal carrying charges	$ 351,000

e. Total Carrying Charges (item b plus item d) $ 626,000

147. Determination of Cost of Amortization.

a. Federal Amortization of Obsolescence and Depreciation

(1) Fixed parts - 50 years' life (4% interest) 0.655% annually.

(2) Movable parts - 25 years' life (4% interest) 2.401% annually.

(3) Federal allocation of land, etc. -

(50 years, 4%) 0.655% annually.

b. Non-Federal Amortization

(1) 50 years (5% interest) 0.478% annually.

ESTIMATED COSTS

RUMFORD, DIXFIELD, BUCKFIELD, AND OXFORD RESERVOIRS

148. Summary.

ESTIMATED FIRST COSTS

Reservoir	Federal	Local	Total	Cost per Acre-foot
Rumford	$5,581,000	$5,581,000	$11,162,000	$37.80
Dixfield	659,000	239,000	898,000	22.30
Buckfield	1,251,000	790,000	2,041,000	33.50
Oxford	1,847,000	1,847,000	3,694,000	40.20
TOTAL	$9,338,000	$8,457,000	$17,795,000	

149. Rumford Reservoir.

Damages

Land to Elev. 665	17,000	acres	at $	45	$ 765,000
Buildings to Elev. 655		lump sum			850,000
Cemeteries relocated	1,740	graves	at	50	87,000
Power Privileges	1,000	horsepower	at	40	40,000
Railroads relocated	7	miles	at	88,570	620,000
Highways relocated	33	miles	at	54,500	1,800,000
Telephones relocated	40	miles	at	4,000	160,000
Telegraph relocated	7	miles	at	2,000	14,000
Power lines relocated	20	miles	at	3,000	60,000
Sub-Total					$4,396,000
Contingencies & Overhead		35%			1,539,000
TOTAL DAMAGES					$5,935,000
Reservoir Clearing		lump sum			$ 340,000

Structures

Dam-site clearing	60	acres	at	150	$ 9,000
Earth excavation - structures	1,126,000	cubic yards	at	.25	281,500
Earth excavation-spillway	86,000	cubic yards	at	.30	25,800
Rock excavation - structures	175,000	cubic yards	at	2	350,000
Rock excavation - tunnels	49,500	cubic yards	at	8	396,000
Drilling and grouting	4,000	linear feet	at	10	40,000
Cut-off - steel sheet piling	54,800	square feet	at	1.25	68,500
Concrete - mass	18,700	cubic yards	at	12	224,400
Concrete - hollow dam	18,100	cubic yards	at	20	362,000
Concrete - outlets and tunnels	38,600	cubic yards	at	14	540,400
Reinforcement	2,260	tons	at	120	271,200

Rumford Reservoir (continued)

Structures (continued)

Embankment - rolled fill	42,600 cubic yards at		.50	$ 21,300
Embankment - hydraulic fill	937,400 cubic yards at		.50	468,700
Gates and operating devices	lump sum			160,000
Miscellaneous steel	lump sum			20,000
Gate house super-structure	84,000 cubic feet at		.80	67,200
TOTAL STRUCTURES				$3,306,000
Miscellaneous				
Stream diversion	lump sum			$ 200,000
Service power lines	6 miles	at 3,000		18,000
Service roads	lump sum			3,000
Operator's quarters	lump sum			5,000
TOTAL MISCELLANEOUS				$ 226,000
Sub-Total Construction Cost - Clearing, Structures and Miscellaneous				$3,872,000
Contingencies & Overhead	35%			1,355,000
TOTAL CONSTRUCTION COST				$5,227,000
TOTAL ESTIMATED FIRST COST				$11,162,000
Estimated Cost per Acre-foot				$ 37.80
Estimated Cost per Square Mile of Drainage Area				$ 11,600
Estimated Cost per 1000 Cubic Feet per Second Reduction in Flood Discharge at Lisbon Falls, Maine, for a Flood Similar to that of March, 1936				$ 342,000

Estimated Federal Cost $5,581,000 (50% of Total Estimated Cost)

Estimated Local Cost $5,581,000 (50% of Total Estimated Cost)

Movable Parts

Gates and operating devices	$160,000	
Crane (included in gate house)	33,600	
TOTAL		$ 195,600

150. Dixfield Reservoir.

Damages				
Land to Elev. 460	3,000 acres	at $	20	$ 60,000
Buildings to Elev. 450	lump sum			50,000
Power privileges	50 horsepower	at	40	2,000
Highways relocated	.7 mile		50,000	35,000
Telephones relocated	6 miles	at	2,500	15,000
Power lines relocated	5 miles	at	3,000	15,000
Sub-Total				$ 177,000
Contingencies & Overhead	35%			$ 62,000
TOTAL DAMAGES				$ 239,000
Reservoir Clearing	lump sum			$ 60,000
Structures				
Dam-site clearing	7 acres	at	150	$ 1,050
Earth excavation - structures; Earth excavation - spillway	64,000 cubic yards	at	.50	32,000
Cut-off - steel sheet piling	15,000 square feet	at	1.75	26,250
Concrete - hollow dam	2,700 cubic yards	at	20	54,000
Concrete - outlets	6,000 cubic yards	at	20	120,000
Reinforcement	350 tons	at	120	42,000
Embankment - hydraulic fill	106,000 cubic yards	at	.60	63,600
Gates and operating devices	lump sum			25,000
Miscellaneous steel	lump sum			8,600
Gate house superstructure	19,000 cubic feet	at	1.50	28,500
TOTAL STRUCTURES				$ 401,000

Dixfield Reservoir (continued)

Miscellaneous

Stream diversion	lump sum	$ 15,000
Service power lines	lump sum	4,000
Service roads	lump sum	3,000
Operator's quarters	lump sum	5,000
TOTAL MISCELLANEOUS		$ 27,000
Sub-Total Construction Cost - Clearing, Structures and Miscellaneous		$ 488,000
Contingencies & Overhead	35%	171,000
TOTAL CONSTRUCTION COST		$ 659,000
TOTAL ESTIMATED FIRST COST		$ 898,000
Estimated Cost per Acre-foot		$ 22.30
Estimated Cost per Square Mile of Drainage Area		7,180
Estimated Cost per 1000 Cubic Feet per Second Reduction in Flood Discharge at Lisbon Falls, Maine, for a Flood Similar to that of March, 1936		$ 130,000

Estimated Federal Cost $659,000 (73% of Total Estimated Cost)

Estimated Local Cost $239,000 (27% of Total Estimated Cost)

Movable Parts

Gates and operating devices	$25,000	
Crane, (included in gate house)	14,250	
TOTAL		$ 39,250

151. Buckfield Reservoir.

Damages

Land to Elev. 355	5,600 acres	at	$ 25	$	140,000
Buildings to Elev. 345	lump sum				80,000
Cemeteries relocated	200 graves	at	50		10,000
Power privileges	500 horsepower	at	40		20,000
Highways relocated	$5\frac{1}{2}$ miles	at	58,200		320,000
Telephones relocated	4 miles	at	2,500		10,000
Power lines relocated	lump sum				5,000
Sub-Total				$	585,000
Contingencies & Overhead	35%				205,000
TOTAL DAMAGES				$	790,000
Reservoir Clearing	lump sum			$	112,000

Structures

Dam-site clearing	50 acres	at	150	$	7,500
Earth excavation - structures	120,000 cubic yards	at	.30		36,000
Earth excavation - dikes	24,000 cubic yards	at	.30		7,200
Rock excavation - structures	4,000 cubic yards	at	3		12,000
Rock excavation - spillway	110,000 cubic yards	at	2		220,000
Drilling and grouting	1,200 linear feet	at	10		12,000
Cut-off - concrete key	830 cubic yards	at	12		9,960
Concrete - mass	2,200 cubic yards	at	12		26,400
Concrete - outlets	5,800 cubic yards		15		87,000
Reinforcement	230 tons	at	120		27,600
Embankment - rolled fill	60,000 cubic yards	at	.50		30,000
Embankment - hydraulic fill	460,000 cubic yards	at	.50		230,000
Gates and operating devices	lump sum				27,000

Buckfield Reservoir (continued)

Structures (continued)

Miscellaneous steel	lump sum		$ 10,840
Gate house super-structure	13,000 cubic feet at	1.50	19,500
TOTAL STRUCTURES			$ 763,000

Miscellaneous

Stream diversion	lump sum	$ 30,000
Service power lines	lump sum	5,000
Service roads	lump sum	12,000
Operator's quarters	lump sum	5,000
TOTAL MISCELLANEOUS		$ 52,000

Sub-Total Construction Cost - Clearing, Structures and Miscellaneous		$ 927,000
Contingencies & Overhead	35%	324,000
TOTAL CONSTRUCTION COST		$1,251,000
TOTAL ESTIMATED FIRST COST		$2,041,000
Estimated Cost per Acre-foot		$ 33.50
Estimated Cost per Square Mile of Drainage Area		$ 13,100
Estimated Cost per 1000 Cubic Feet per Second Reduction in Flood Discharge at Lisbon Falls, Maine, for a Flood Similar to that of March, 1936		$ 272,000

Estimated Federal Cost $1,251,000 (61% of Total Estimated Cost)

Estimated Local Cost $ 790,000 (39% of Total Estimated Cost)

Movable Parts

Gates and operating devices	$27,000	
Crane (included in gate house)	9,750	
TOTAL		$ 36,750

152. Oxford Reservoir.

Damages				
Land to Elev. 335	7,000 acres	at $	45	$ 315,000
Buildings to Elev. 325	lump sum			240,000
Cemeteries relocated	400 graves	at	50	20,000
Power privileges	250 horsepower	at	40	10,000
Railroads relocated	3-3/4 miles	at	121,000	454,000
Highways relocated	8 miles	at	47,500	380,000
Telephones relocated	6 miles	at	3,000	18,000
Telegraph relocated	3-3/4 miles	at	1,870	7,000
Power lines relocated	5 miles	at	3,000	15,000
Sub-Total				$1,459,000
Contingencies & Overhead	35%			511,000
TOTAL DAMAGES				$1,970,000
Reservoir Clearing	lump sum			$ 140,000
Structures				
Dam-site clearing	40 acres	at	150	$ 6,000
Earth excavation - structures	40,000 cubic yards	at	.30	42,000
Earth excavation - dikes	100,000 cubic yards			
Rock excavation - structures	3,900 cubic yards	at	3	11,700
Drilling and grouting	1,300 linear feet	at	10	13,000
Cut-off - concrete key	85 cubic yards	at	14	1,190
Concrete - mass	10,500 cubic yards	at	12	126,000
Concrete - wing walls	24,800 cubic yards	at	15	372,000
Concrete - outlets	2,900 cubic yards	at	15	43,500
Reinforcement	1,100 tons	at	120	132,000
Embankment and dikes - rolled fill	475,000 cubic yards	at	.60	285,000

Oxford Reservoir (continued)

Structures (continued)

Gates and operating devices	lump sum	$ 30,000
Miscellaneous steel	lump sum	10,160
Gate house superstructure	18,300 cubic feet at $ 1.50	27,450
TOTAL STRUCTURES		$1,100,000

Miscellaneous

Stream diversion	lump sum	$ 25,000
Service power lines	lump sum	4,000
Service roads	lump sum	3,000
Operator's quarters	lump sum	5,000
TOTAL MISCELLANEOUS		$ 37,000

Sub-Total Construction Cost - Clearing, Structures and Miscellaneous		$1,277,000
Contingencies & Overhead	35%	447,000
TOTAL CONSTRUCTION COST		$1,724,000
TOTAL ESTIMATED FIRST COST		$3,694,000
Estimated Cost per Acre-foot		$ 40.20
Estimated Cost per Square Mile of Drainage Area		$ 16,000
Estimated Cost per 1000 Cubic Feet Per Second Reduction in Flood Discharge at Lisbon Falls, Maine, for a Flood Similar to that of March, 1936		$ 273,000

Estimated Federal Cost $1,847,000 (50% of Total Estimated Cost)

Estimated Local Cost $1,847,000 (50% of Total Estimated Cost)

Movable Parts

Gates and operating devices	$30,000	
Crane (included in gate house)	13,750	
TOTAL		$ 43,750

COPY of 1/258 Androscoggin

WAR DEPARTMENT
Office of Division Engineer
North Atlantic Division
14th Floor - Maritime Exchange Bldg.
80 Broad Street
New York, N. Y.

Androscoggin R. 2/3.7 August 25, 1937.

Subject: Review Report - Androscoggin River, Maine.

To: The Chief of Engineers, U. S. Army.

S Y L L A B U S

The Division Engineer finds that no revision is required of the conclusions and recommendations contained in House Document No. 646, Seventy-first Congress, 3d session. Improvement of the Androscoggin River for navigation is unwarranted. Irrigation is unnecessary. The river is well adapted to power production. Existing power development is extensive and ample for present needs. The control of floods by reservoirs, local protection and channel improvements is possible, but not economically justified at the present time. Reservoir studies indicate the advantage of a four-reservoir system for combined flood control and power purposes. The future economic justification of this plan is possible.

- - - - - - - - - -

1. AUTHORITY - This report is submitted pursuant to the following authority:

(a) "RESOLVED, By the Committee on Flood Control of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors, created under section 3 of the river and harbor act, approved June 13, 1902, be, and is hereby requested to report to this Committee at the earliest practicable date, the results of the additional studies and investigations made on the Androscoggin River, to take into account important changes in economic factors, additional stream flow records, or factual data developed as a result of the recent severe flood, with a view to revising the report on this river printed as House Document No. 646, Seventy-first Congress, 3d session;" (adopted March 27, 1936).

(b) "RESOLVED BY THE COMMITTEE ON COMMERCE OF THE UNITED STATES SENATE, That the Board of Engineers for Rivers and Harbors created under section 3 of the River and Harbor Act approved June 13, 1902, be and is hereby requested to review the report on Androscoggin River, Maine, submitted in House Document No. 646, Seventy-first Congress, 3d session, with a view to determining whether any modification of the recommendations contained therein is deemed advisable as a result of the recent severe floods;" (adopted March 28, 1936).

2. PRIOR REPORT - The report under review on the Androscoggin River, submitted under the provisions of House Document No. 308, Sixty-ninth Congress, 1st session, was published as House Document No. 646, Seventy-first Congress, 3d session. This report considered navigation, flood control, power development, and irrigation. It concluded that no development for these purposes was economically advisable, and recommended that there be no Federal participation in any works of improvement with a view to modifying the existing conditions.

3. PROJECTS - There have been no previous projects and there are no existing Federal projects on the Androscoggin River.

4. <u>DESCRIPTION</u> - The watershed of the Androscoggin River lies principally in western Maine with part of the headwater area, comprising about 20 per cent of the total, lying in New Hampshire. The basin has a length of 110 miles, maximum width of 55 miles, and a total area of 3,470 square miles.

5. The river rises at the Canadian border near the boundary between the states of Maine and New Hampshire, flows in a southerly direction for about 75 miles, then flows east for about 70 miles into the State of Maine, then flows generally south for 60 miles to tidewater at Brunswick, Maine. The mouth of the river is its outlet into the west end of Merrymeeting Bay, a tidal basin through the eastern portion of which the Kennebec River flows. The total length of the river is about 200 miles.

6. The principal tributaries of the Androscoggin River are the Magalloway, Swift, Webb, Dead, Nezinscot, and Little Androscoggin Rivers. The largest of these is the Magalloway which has a drainage area of 500 square miles.

7. A total of 143 square miles of the drainage area is occupied by lakes and ponds which exercise complete or partial control over approximately 1,400 square miles, or 40 per cent of the entire basin area.

8. In general elevation, the Androscoggin watershed is higher than that of any other eastern river in the United States. In the 167 miles from Umbagog Lake, which is 1,244 feet above sea level, to tidewater the fall averages nearly 7.5 feet per mile. The maximum fall is more than 100 feet per mile in a reach 1.7 miles long at Rumford, Maine.

9. The upper portions of the basin are mountainous, almost entirely covered by forests, and contain comparatively few settlements, most of which are located close to the streams. Along the lower portion of the river there is a considerable volume of manufacturing of cotton goods, pulp, and paper. The lower portion of the basin is, however, mainly hilly and wooded with some cultivated areas.

10. According to the census of 1930, the total population of the basin was nearly 150,000, approximately 124,000 in Maine and 26,000 in New Hampshire. The largest cities in the Maine portion of the watershed are Lewiston, Auburn, Rumford, Brunswick, and Lisbon, with a total population of 73,842. The largest is Lewiston with a population of 34,939. The principal city in the New Hampshire portion of the watershed is Berlin with a population of 20,018.

11. <u>HYDROLOGY</u> - The Androscoggin watershed is characterized by frequent, but short, periods of heavy precipitation rather uniformly distributed throughout the year. The probability of torrential rains is somewhat higher for the month of September, coinciding with the season of coastwise hurricanes from the tropics. The mean annual temperature is about 42.7 degrees Fahrenheit. A heavy annual snowfall, varying from about 77 inches on the coast to about 130 inches on the northern headwaters, results from the sustained low winter temperatures. The average annual precipitation, including water equivalent of the snowfall, is about 39.4 inches. Mean annual run-off is about 22.65 inches, or about 58 per cent of the precipitation.

12. Floods on the Androscoggin may be the result of heavy precipitation from extratropical cyclones. These may pass over the watershed at any time of the year. Floods also may result from the rapid run-off from snow melted by sudden increases in temperature or by heavy rainfall. Tropical cyclones, or hurricanes, may also reach the watershed and bring intense rainfall. These storms occur only in the summer and early fall. At this time ground conditions are usually such that much of the rainfall is absorbed and large floods do not often result.

13. Studies show that rare floods may have peak discharges approaching 90,000 c.f.s. at Rumford. The flood of March, 1936, the greatest of record on the Androscoggin River, reached a peak discharge of 74,000 c.f.s. at Rumford and 135,000 at Auburn, Maine. This flood resulted from a favorable combination of thawing temperatures, more than average depth of snow cover, and heavy precipitation. During the preceding three-month period, snowfall had exceeded the average and temperatures had been less than normal so that by March the watershed was under a deep snow cover which had not been appreciably depleted before the March storms. These storms came from the Gulf of Mexico and passed up the Atlantic seaboard with a northward movement of tropical air masses. The cooling of this moist air mass by the snow-covered surface of the watershed resulted in heavy precipitation and rapid melting of snow cover. These conditions caused a large volume of run-off.

14. NAVIGATION - No improvement of the Androscoggin River in the interests of navigation has ever been undertaken by the United States. Present depths in the tidal portion of the river are not known, but it is probable however that the controlling depth to Brunswick is not greater than the three feet indicated by a survey in 1881. The conclusions of the report under review were that any extension of navigation through or above tidewater would not be economically advisable. New developments which would require revision of these conclusions have not taken place, nor is there any reason or demand for improving the tidal portion of the river below Brunswick. Navigation could be extended above Brunswick only at high cost by means of locks and dams where necessary. Above Lewiston and Auburn there are no towns of commercial importance to be benefited if navigation were extended, and the tributary districts are largely undeveloped. Transportation by railroad and highway is adequate for the present needs.

15. IRRIGATION - The cultivated areas in the valley are small and the rainfall varies from 44 inches near the coast to 33 inches in the northern portion of the basin. This rainfall is ample for existing and prospective agricultural needs, and irrigation is unnecessary.

16. POWER DEVELOPMENT - The Androscoggin River is highly developed for power generation. With a total drainage area equal to 10.5 per cent of the area of the State of Maine, the installed generating capacity is 45 per cent of the total for the entire state. There are within the basin 53 water power develop-

ments of more than 100 horsepower each, which have a total installed generating capacity of nearly 248,000 horsepower. This is considerably in excess of present requirements, and most of the plants have the equipment and water available to furnish a large additional amount of electric power at little increase in operating costs. If this surplus power could be sold, it would materially reduce the unit cost of production.

17. INCIDENTAL FLOOD CONTROL FROM EXISTING POWER STORAGE RESERVOIRS - The total existing storage in the basin amounts to 738,000 acre-feet, equivalent to 213 acre-feet per square mile of drainage area. This storage exercises a degree of control over 1,400 square miles or 40 per cent of the entire drainage basin. It consists largely of natural lakes at the outlets of which control works have been built. These are under the jurisdiction of the power interests and are operated to impound spring run-off for release later during the low flow periods. These lakes are situated principally in the upper portion of the basin and while they ameliorate flood flows, their effect is insufficient to prevent damaging floods in the more populous lower reaches of the basin.

18. FLOOD LOSSES - The amount of damages caused by the flood of 1936 was found by census of the individual sufferers to be about $3,574,000, of which $2,756,000 represents the loss due to direct damage and $818,000 to indirect damage. Of the total loss that suffered in the Maine portion of the watershed amounted to about $3,419,000, and that in the New Hampshire portion to about $155,000. In order to take into account the indirect damages unreported but known to exist, the reported amount of indirect damages ($818,000) was doubled in computing flood control benefits. The average annual damage computed from stage versus frequency curves and stage versus damage curves was found to be $453,500.

19. <u>POSSIBLE METHODS OF FLOOD CONTROL</u> - It was found that some degree of reduction of flood losses may be effected by removal of artificial obstructions such as dams, bridges, and buildings. In no instance was it found that the lessening of flood damages was sufficient to warrant removal for flood control purposes alone. State authority could eliminate these flood hazards at some future date when replacement becomes necessary as a result of the natural course of events.

20. The control of floods at the principal damage centers by means of levees and river walls was studied. This method of protection is positive up to the height of levee or river wall provided. Its influence is entirely local and provides no incidental benefits such as would result from control by reservoirs. No instance was found where full protection by levees was economically justified. Under a coordinated flood control plan some local protection would be involved after the reduction in flood heights effected by the extent of reservoir control adopted.

21. Control of floods on the Androscoggin River by means of reservoirs was indicated as the most desirable method. Study was made to locate all sites suitable for construction of dams of sufficient height to control a flood run-off equal in volume to that of the 1936 flood. Eliminations were made on the basis of size of drainage area controlled, characteristics of run-off from the area, location with respect to flood damage centers, cost of construction, and value of benefits accruing from the measure of flood control afforded.

22. PRACTICABILITY OF PROVIDING FLOOD CONTROL WORKS - In the following economic discussion, interest rates of 5 per cent on non-Federal investments and 4 per cent on Federal investments have been used in computing the annual costs of the proposed works.

a. Local protection from floods can be accomplished by specific treatment at the various localities. The result of investigation shows however that the ratio of benefits to costs varies from 0.037 to 0.590 depending upon the locality. It was concluded that this method of protection is not economically advisable at the present time.

b. General control of floods by means of a system of four reservoirs, or a lesser number selected therefrom, was found to be uneconomical. The most advantageous reservoir plan is composed of Rumford on the main stream, Dixfield on the Webb River, Buckfield on the Nezinscot River, and Oxford on the Little Androscoggin River. Considered on a basis of benefits to flood control only, this reservoir combination has annual benefits of $374,100. The annual carrying charges are $1,000,000 and the ratio of benefits to charges is 0.37. The total first cost of this four-reservoir combination is $17,795,000. They would provide 488,300 acre-feet of storage, and would control 2,602 square miles of drainage area or 74 per cent of the entire basin. This includes the 1,100 square miles upstream from the proposed Rumford reservoir which are partially controlled by 688,000 acre-feet of existing power storage.

c. A three-reservoir system of the reservoirs at Rumford, Dixfield, and Buckfield shows annual benefits to flood control of $359,200. The first cost for this system is $14,101,000 for which the annual carrying charges are $793,000. Ratio of annual benefits to annual charges is computed as 0.45. This system would provide 396,300 acre-feet of storage and control 2,371 square miles, including 1,100 square miles partially controlled by existing storage.

d. The Rumford reservoir alone, estimated to have a first cost of $11,162,000, shows annual flood control benefits of $322,700 and annual carrying charges of $626,000, a ratio of benefits to charges of 0.52. This reservoir would provide 295,000 acre-feet and control 2,090 square miles, inclusive of 1,100 square miles now largely controlled by power storage.

23. The Rumford reservoir is the only one which shows economic possibilities for a development to provide combined storage for flood control and power. Assuming that there existed a demand sufficient to absorb the power that could be generated at existing and potential downstream plants from the increased flow, the value of combined benefits to flood control and power resulting from operation of Rumford reservoir was found to be $862,700. The first cost of the combined flood control and power reservoir is estimated at $16,063,000, and carrying charges are computed to be $1,124,000. The ratio of annual benefits to annual charges is 0.77.

24. <u>VIEWS AND RECOMMENDATION OF THE DISTRICT ENGINEER</u> - In connection with the review of the "308" Report under consideration, the District Engineer states that extension of navigation through or above tidewater would not be economically advisable at the present time. Irrigation is not necessary. The supply of power is ample for present demand, and further development of hydro-electric power is improbable in the immediate future. Additional reservoirs of large capacity for flood control alone or for the combined development of flood control and power do not appear to be economically justified at present. At some future time the economic justification of one or more of the proposed reservoirs may result because of increased demand for power. The future justification of flood control reservoirs alone cannot be foreseen. Additional power conservation storage, of sufficient capacity to impound the large spring floods, to produce power at the site, and to involve operation to supply incidental benefits to downstream power developments during the off-flood-peak seasons, would increase the measure of incidental flood control already existing.

25. <u>VIEWS OF THE DIVISION ENGINEER</u> - The Division Engineer concurs with the views and recommendations of the report under review, which are substantially repeated in the views and recommendations of the District Engineer in the preceding paragraph. The Androscoggin basin suffered serious damage during the unprecedented flood of March 1936. The existing storage of 738,000 acre-feet exercises a degree of control over 1,400 square miles or 40 per cent

of the basin, resulting in considerable reduction of flood stages. Annual benefits, resulting from the proposed additional flood control plan, do not warrant Federal participation in such improvement at the present time under existing law. Future justification of the additional flood control plan is possible.

26. CONCLUSION -

a. No improvement of the Androscoggin River for navigation, power development, flood control, or irrigation is economically advisable at the present time.

b. It is recommended that this report be not published at this time due to investigations under the Flood Control Act of 1936 which are now under way.

E. L. DALEY,
Colonel, Corps of Engineers,
Division Engineer.

Incl. accpg.:
2/3.4, in tripl.

PRELIMINARY EXAMINATION OF THE ANDROSCOGGIN RIVER,

MAINE AND NEW HAMPSHIRE, FOR FLOOD CONTROL

Syllabus

The District Engineer finds that, although the Androscoggin Basin is subject to appreciable flood losses, the annual flood damage is comparatively small and complete flood protection cannot be economically provided at the present time. General flood protection by means of levees or channel improvement is not practicable and local flood protection by these means is not justified at the present time. Reservoir control is entirely practicable, however, and it is possible that partial protection by this means may be justified. It is also possible that, if further development takes place in the valley, the need and justification for flood control may increase.

The District Engineer recommends that a survey be made to determine the extent of reservoir control which may be justified.

The District Engineer further recommends that the states be encouraged to provide regulation for the elimination of channel encroachments and for the control of existing storage and also that the flood warning and flood forecasting services of all agencies be extended and correlated through the United States Weather Bureau.

War Department
United States Engineer Office
Boston, Massachusetts

October 11, 1937

Subject: Report on a Preliminary Examination of the Androscoggin River, Maine and New Hampshire, for Flood Control

To: The Division Engineer, North Atlantic Division, New York, N.Y.

1. Authority. - This report is submitted in accordance with an Act (Public No. 812, 74th Congress) approved June 25, 1936, authorizing a "preliminary examination of the Androscoggin River, in Maine and New Hampshire, and its tributaries, with a view to control of their floods" and the Flood Control Act (Public No. 738, 74th Congress) approved June 22, 1936, which directs in part as follows:

"Section 6. The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control at the following-named localities, * * * * * * * * * * Androscoggin River, Maine * * * * * * * * * * ."

2. Prior Reports. - The only prior reports made on this river pertaining to flood control are the report made under the provisions of House Document No. 308, 69th Congress, 1st Session (printed as House Document No. 646, 71st Congress, 3d Session) and the review thereof (not printed) dated December 30, 1936, which was made under the authority of resolutions of the Committee on Commerce of the United States Senate and the Committee on Flood Control of the House of Representatives.

3. Existing Project. - There are no existing or prior projects for flood control for the Androscoggin River.

4. Description of the Watershed. - The Androscoggin River Basin is located principally in western Maine, with part of the headwater area, about 20 per cent of the total, lying in New Hampshire. The basin has a length of 110 miles, a maximum width of 55 miles, and a total drainage area of 3,470 square miles. The lake and pond area, amounting to 143 square miles or 4.1 per cent of the total basin area, exercises a considerable degree of control over about 1,400 square miles, or 40 per cent of the total basin area. The topography ranges from rough and mountainous in the upper portion to broad, low hills with considerable lake and swamp area in the lower portions. The river and its tributaries follow irregular, winding courses over deep glacial overburden beneath which the pre-glacial bedrock drainage courses are completely buried. Where the bedrock is exposed or close to the surface, as it is in numerous short channel reaches in the high hills and mountains, the channel has not been incised into the rock more than 5 to 10 feet. The bedrock is predominantly granite, schist and gneiss, with occasional areas of slate and other metamorphic rock. The overburden consists mainly of gravelly, somewhat silty sands.

5. Development Within the Basin. - The total population of the basin in 1930 was about 150,000, most of which is contained in the six largest cities, all over 3,000 population, which are located on the main stream. The upper part of the basin is largely forest covered and has comparatively few settlements. In the lower half of the basin there is a large volume of manufacturing, the principal products being cotton goods, pulp and paper. The lower part of the basin has good highways and is served by the Maine Central and Grand Trunk Railroads.

6. Description of the Main River. - The Androscoggin River rises at the Canadian border near the boundary between the States of Maine and New Hampshire, in mountainous territory, at an elevation of about 2,600 to 2,900 feet above mean sea level. From Umbagog Lake, about 35 miles south of the headwaters, the river flows in a southerly direction for about 35 miles, then turns easterly into Maine for about 70 miles, and thence flows in a general southerly direction for 60 miles to tidewater at Brunswick, Maine. The main stream has an average slope over its 200-mile length of about 13 feet per mile. Much of the fall is concentrated near Berlin, New Hampshire and at Rumford, Maine. The average discharge for the 9-year period of record at Auburn, Maine, (drainage area, 3,260 square miles) is 5,420 c.f.s.; the maximum, 135,000 c.f.s.; and the minimum 465 c.f.s.

7. Tributaries. - The principal tributaries are shown in the following table:

TABLE I - TRIBUTARIES OF THE ANDROSCOGGIN RIVER

River	Drainage Area (sq.mi.)	Location		Distance of Mouth from Tidewater (miles)	Discharge of Record c.f.s./sq.mi.		
		Headwaters	Mouth		Max.	Min.	Mean
Magalloway	500	At International boundary 13 mi. W. of Big Island, Me.	Errol, N. H.	165	Completely regulated		
Swift	135	5 mi. N. of Houghton, Me.	Rumford, Me.	82	136.84	.05*	1.87
Webb	125	3 mi. N.E. of Weld, Me.	Dixfield, Me.	75	No gaging station		
Dead	100	4 mi. N. of Vienna, Me.	5 mi. N. of Leeds, Me.	46	No gaging station		
Nezinscot	275	2 mi. N.W. of Redding, Me.	4 mi. N. E. of Turner, Me.	38	No gaging station		
Little Androscoggin	380	Bryant Pond, Me.	Auburn, Me.	24	46.58	.01*	1.83

* Regulated by controlled storage.

8. <u>Development of Water Resources</u>. - The Androscoggin River has been very highly developed for power. Of an estimated 353,000 horsepower available, 246,469 horsepower in 42 installations have been developed. Twenty-eight installations, utilizing 775 feet of head and totalling 239,873 horsepower are on the main stream and the remaining 14 installations, with 310 feet of head and totalling 6,596 horsepower, are on the tributaries. The storage capacity is equally well developed, amounting to about 740,000 acre-feet for the entire drainage area, or about 213 acre-feet per square mile. Most of this storage is contained in the large natural lakes in the upper basin which are controlled for power storage. The 1,095 square miles above Errol, New Hampshire, about 32 per cent of the total

basin area, are very completely controlled, containing 678,000 acre-feet of storage.

9. Hydrology. - The climate is variable, with temperatures ranging from below freezing for the two or three winter months to the high summer temperatures required to support a varied plant life. The mean annual precipitation of 39.4 inches is rather uniformly distributed throughout the year, but it is characterized by short, frequent periods of heavy rain. The annual snowfall is quite heavy, ranging from about 77 inches near the coast to 130 inches on the northern headwaters. Comparative data are shown in the following table:

TABLE II - MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION - ANDROSCOGGIN RIVER BASIN

Month	Mean Temperature (°F.)	Mean Precipitation (inches)	Equivalent Run-off in Inches at Rumford, Me. (D.A. - 2090 sq.mi., or 60% of total basin)
Jan.	16.0	3.03	1.36
Feb.	17.4	2.86	1.16
Mar.	28.8	3.35	2.07
Apr.	41.2	2.95	3.88
May	53.3	3.31	3.77
June	62.0	3.53	2.09
July	68.0	3.60	1.38
Aug.	65.2	3.64	1.24
Sept.	58.0	3.43	1.23
Oct.	47.3	3.24	1.41
Nov.	34.1	3.39	1.65
Dec.	21.3	3.07	1.41
Annual	42.7	39.40	22.65

10. Records of Precipitation. - There are 9 observation stations for precipitation maintained by the United States Weather Bureau in the Androscoggin watershed. The data concerning these stations are listed in the following table:

TABLE III - PRECIPITATION STATIONS - ANDROSCOGGIN RIVER BASIN

Station	Elevation (Feet above M.S.L.)	Period of Record	Length of Record (Years)	Remarks
Oquossuc,,Me.	1534	1900-1930	31	1902,03,07,09,12-16, 30 records incomplete
Upper Dam, Me.	1484	1886-1935	50	
Middle Dam, Me.	1430	1905-1935	31	1935 record incomplete
Aziscohos Dam, Me.	1528	1911-1933	23	1933 record incomplete
Errol, N. H.	1260	1885-1935	51	1929, 30, 32, 34 records incomplete
Milan, N. H.	1190	1887-1898 1926-1935	22	1898, 1926 records incomplete
Berlin, N. H.	1110	1887-1903 1918-1935	35	
Rumford, Me.	505	1894-1935	42	
Lewiston, Me.	182	1875-1935	61	

11. <u>Records of Stream Flow</u>. - There are 11 stream gaging stations in the basin maintained by the United States Geological Survey. Data concerning these stations are given in the following table:

TABLE IV - GAGING STATIONS - ANDROSCOGGIN RIVER BASIN

Location of Gaging Station	Drainage Area (sq.mi.)	Period of Record	Discharge of Record in Cubic Feet Per Second		
			Mean	Maximum	Minimum
Androscoggin River					
Errol, N. H.	1090	1905-1923	**		
Berlin, N. H.	1380	1913-1922	2180	14,300	*
Gorham, N. H.	1390	1929-1936	2360	19,900	960*
Shelburne, N. H.	1500	1903-1907	-	15,600	*
Rumford, Me.	2090	1892-1936	3480	74,000	*
Dixfield, Me.	2230	1902-1908	4940	-	*
Gulf Island, Me.	2860	1936	-	118,000	1550*
Auburn, Me.	3260	1928-1936	5420	135,000	465*
Magalloway River					
Aziscohos Dam, N. H.	233	1912-1935	**		
Swift River					
Roxbury, Me.	95	1929-1936	178	13,000	5
Little Androscoggin River					
South Paris, Me.	76	1913-1924 1931-1936	139	6,980	1

* Flow affected by controlled storage.
** Completely regulated.

12. Accuracy of Gaging Stations. - In general, the accuracy of the stream gaging stations in the basin is very good. The discharge is computed from the flow over dams or through gates or wheels at five of the eleven stations. Good rating curves have been developed for most of the stations for medium and high stages. The records are considered very good, except during periods of ice cover, when they are fair.

13. General Flood Situation. - About 40 per cent of the Androscoggin watershed is at least partially controlled by the natural lakes and ponds, most of which are regulated for power storage. This storage, although it does not provide positive flood control at all times, is quite effective in reducing flood stages for ordinary floods. It is not, however, generally effective for extreme floods. The extreme floods in this basin, on the other hand, are possible only from the

combination of heavy rain and melting snow, and their occurrence is comparatively infrequent. The resulting damages are confined generally to the industrial areas near the river channel in the lower portions of the watershed.

14. Types of Storms. - The storms which occur in the Androscoggin Basin may be classified into three general types as follows: (1) extratropical cyclones; (2) tropical hurricanes; and (3) rain storms caused by the rapid displacement upward of a warm air mass by a colder, denser air mass, usually accompanied by an extratropical cyclone or a tropical hurricane. Of these, the extratropical cyclones are the most numerous. They occur throughout the year and are the principal factor in providing the uniform year-round precipitation of the basin. The more severe rains are caused by the second and third types of storms. The tropical hurricanes, however, are restricted generally to the summer and early fall seasons, - a time when the ground conditions are such that much of the heavy rainfall can be absorbed without causing unusual flooding. The most dangerous storms, from a flood standpoint, are the rains caused by the movements of warm and cold air masses. Such storms may occur at any time of the year and the most severe floods in the basin are caused by this type of disturbance bringing unusual temperatures and heavy rainfall to a snow-covered basin.

15. Effect of Snow. - Recent snow surveys of storage operators in the basin indicate that there is usually an accumulated water equivalent of about 10 inches in the annual snow cover at the time of the spring "thaw" and that this cover is usually converted to run-off in one continuous period of about 10 to 15 days. Additional studies on snow run-off made by this office support these observations and lead to the conclusion that snow is usually a contributing factor to the spring floods in this basin and it may be the principal cause.

16. Effect of Ice. - Ice is also a factor in the floods which occur early in the spring. It is not always, however, of great importance. The Androscoggin River flows in a general southerly directiona and normally the ice in the lower reaches softens and goes out sooner than that in the upper reaches and headwaters. On the other hand, when the spring break-up occurs early, ice jams, comprising thick, solid "blue ice", are likely to form at obstructions in the river. On these occasions serious damage may be caused by these ice jams, as during the flood of March, 1936, when a railroad bridge at Brunswick was carried out by the force of the jam.

17. Record of Past Floods. - The six highest floods of record on the Androscoggin River at Rumford, Maine (drainage area, 2,090 square miles, of which 1,096 square miles are completely controlled) were as follows:

TABLE V - RECORD FLOODS - ANDROSCOGGIN RIVER AT RUMFORD, MAINE

Date	Average 24-Hour Discharge (c.f.s.)	Instantaneous Peak Discharge (c.f.s.)	Average Run-off for One Day in c.f.s. per sq. mile
March 19, 1936	68,300	74,000	32.6
April 15, 1895	55,230	-	26.4
November 5, 1927	39,100	-	18.7
March 2, 1896	39,010	-	18.6
May 18, 1893	38,060	-	18.2
March 13, 1936	35,600	38,200	17.0

18. Flood Frequency. - Spring, because of the occurrence of snow run-off with or without rain, is the season of high water and floods in the Androscoggin Basin. Of all peak discharges greater than the average annual flood over the period of record from 1893 to 1936 at Rumford, one-third occurred during the month of April and two-thirds occurred during the months of March, April and May. The

computed frequency for discharges at Rumford, Maine, is as follows:

Period	24-Hour Discharge in c.f.s.
Once in 1 year	20,000
Once in 10 years	38,000
Once in 50 years	54,000
Once in 75 years	59,000
Once in 100 years	62,000

19. Description of the Worst Flood of Record. - The March, 1936, flood in this basin was the greatest on record. The maximum discharge of 68,300 c.f.s. exceeded the highest previously recorded (in 1895) by nearly 25 per cent and the flood losses were many times greater than any previously suffered. The flood was caused by a succession of two storms within a period of 11 days. Rainfall for the 11-day period was heavy throughout the entire New England area, varying from a few inches along the coast to a maximum of about 20 inches in the White Mountains, which are the common headwaters of the Connecticut, Merrimack, Kennebec and Saco Basins, as well as the Androscoggin Basin. Four lives were lost in the Androscoggin Basin during the flood and over 1,500 families, involving about 6,000 people, were temporarily homeless. About 2,000 buildings were affected by the flood. Eighteen bridges were wholly or partially destroyed and ten additional bridges suffered some damage. Although the actual area flooded was not large, several towns were practically cut off from the outside world for from one to four days as railroad, highway, telephone and telegraph facilities were disrupted. Several towns were temporarily without light, power and water. The depth of water in the area flooded varied greatly. In the towns and cities a few principal streets were covered to depths of from one to five feet generally, although depths as great as 15 feet were reported in Brunswick, Maine.

20. Flood Damages. - The only complete data on flood damages available for this basin are those collected after the flood of March, 1936. These figures, however, are very reliable, having been obtained by means of a thorough census of the individual sufferers in the basin shortly after the flood. The results of the census are shown in the following table. Of the total damages of $4,392,000 in the basin, $4,232,000, or 96 per cent were in the State of Maine and the remainder, only 4 per cent, in New Hampshire. There is no record of the losses in 1896, but it is known that several highway bridges were washed out and that a large number of logs were carried away. In November, 1927, there were severe losses, especially at Berlin and Gorham, totalling about $400,000 plus an unestimated amount for damage to railways. The losses from all prior floods, however, were probably much less than those for March, 1936, as tabulated below:

TABLE VI - FLOOD DAMAGES - ANDROSCOGGIN RIVER BASIN - MARCH, 1936

Class	Indirect	Direct	Total
Industrial	$ 634,500	$ 867,000	$ 1,501,500
Commercial	87,200	302,200	389,400
Farm and Rural	900	232,600	233,500
Residential	2,600	319,600	322,200
Railroads*	86,800	290,900	377,700
Highways*		550,300	550,300
Utilities	6,000	149,200	155,200
Public Funds (Municipal)		44,200	44,200
Total Reported	$ 818,000	$ 2,756,000	$ 3,574,000
Estimated Unreported	$ 818,000	-	$ 818,000
Grand Total	$ 1,636,000	$ 2,756,000	$ 4,392,000

* Includes bridges.

21. Value and Productivity of Area Subject to Flooding. - Although the area subject to flooding in this basin is not large, a large amount of industrial property is subject to damage during extreme floods. Many of the industries of this region, consisting primarily of textile, boot and shoe, and pulp and paper mills, are located immediately adjacent to the normal river channel. Similarly, the commercial sections of several communities are located near the waterfront. These developments, together with power plants and bridges, are subject to appreciable losses within a comparatively small extent of flooded area. They are seriously affected, however, only by the more extreme floods. The amount of agricultural land flooded may be extensive for the extreme stages but the damage is moderate because the floods usually occur in the spring before crops have been planted. With the exception of bridges which, in many cases, have been rebuilt at higher elevations, most of the developments are subject to recurring damage. In general, the benefits of adequate flood control measures would be confined to the value of the elimination of flood damage to existing developments and would have little effect on increasing the value and productivity of the area subject to flooding.

22. Annual Value of Elimination of Flood Damage. - During the flood damage census, the increments of damage occurring in successive flood stages up to the maximum stage of the 1936 flood were determined. From these data, together with the expected stage-frequency as computed from existing records, a damage-frequency relation was determined. The average annual value of flood loss in that portion of the Androscoggin valley lying below prospective reservoir sites was determined as $453,500. This amount represents the total possible annual flood control benefit which may be realized by the complete elimination of flood damage.

23. Improvement Desired. - No definite opinion on the general plan and extent of flood control measures has been expressed by local interests.

24. Possible Methods of Flood Control. - The more important and most generally applicable methods for flood control are the protection by levees or river walls, control by channel improvement or rectification, diversion of the flood flows and control by reservoirs. In the Androscoggin Basin diversion of flood flows is not practicable. Channel improvements and flood protection by levees or river walls are not applicable for comprehensive flood control throughout the entire valley. These methods have been considered for local flood protection problems and as supplementary protection to possible reservoir control.

25. Reservoir Control. - The most desirable method of obtaining general flood relief in this basin is by means of reservoirs. A study of all possible reservoir sites throughout the basin has revealed that there are several favorable sites for flood control reservoirs which, in conjunction with existing power reservoirs and natural lakes, would afford control for about 75 per cent of the total watershed area. The provision of such reservoir control would afford appreciable reductions in flood stages at the principal damage centers in the basin and would eliminate about 80 per cent of the estimated possible flood damage.

26. Power Development in Conjunction with Reservoir Control. - There is little need for additional power in the Androscoggin Basin at the present time. The export of hydro-electric power from the State of Maine is prohibited by law and the present local needs are well taken care of by existing installations and by interconnection with the adjoining Kennebec Basin. There are several potential power sites in the basin remaining undeveloped and at least one site appears to be favorable for combined flood control and power storage with a power installation. However, in view of the excess generating capacity now available, it would not be practicable to develop any of these

possibilities at the present time. Even if the need for additional power should arise, the demand could be met more economically by redevelopment of existing installations.

27. Local Flood Protection. - An investigation of possibilities for local flood protection by means of channel improvements and levees or river walls at 13 critical damage centers in the basin has revealed that the cost of providing such protection would greatly exceed the benefits which could be realized. There is, however, opportunity for alleviation of the flood situation in many of these and other localities by increasing spillway capacities and the provision of flood gates at the power dams, the provision of greater clearances of bridges, and the elimination of channel encroachment of bridge piers, abutments, etc.

28. Flood Warnings. - Another practical method of lessening flood damages is by means of the flood-warning service maintained by the United States Weather Bureau. When a rainstorm is threatening to pass into the watershed, its probabilities are studied and the companies controlling the storage are informed of the expected rainfall. If the lakes are full and the rainfall threatens to be considerable, the water levels are drawn down in advance of the storm. The amount drawn is determined from the run-off records of the companies and depends on the saturation of the ground, snow cover, the season of the year, etc., as well as on the probable rainfall. By this means storage is made available when the run-off begins, and this not only reduces the flood levels of the lakes, but also lessens the maximum discharge of the river, thus alleviating flood losses. Of course, distant headwater reservoirs must be drawn down in ample time, for if discharged immediately prior to or during the early stages of a flood, they could contribute to an increase in downstream flood stages by filling the valley storage. Two important factors affecting floods in this basin are the extent and water equivalent of the snow cover

and the condition of the ground underneath the snow. Limited observations are now made of precipitation in the form of snow by the United States Weather Bureau, power companies, winter sport organizations and other agencies, but additional estimates by trained observers of the amount of snow cover and its water equivalent are necessary to increase the value of the flood-forecasting service. Extension and correlation of investigations of hydrologic conditions in the basin through cooperation of all agencies concerned, to the end that improved flood forecasts and adequate warning be provided to the companies controlling the storage and to the public, appear to be desirable.

29. Discussion. - Although appreciable flood losses may result from the occurrence of extreme rains on a snow-covered watershed, the frequency of damaging floods is not great and the average annual flood damage is comparatively small. General flood protection throughout the valley by means of levees, river walls, or channel improvements is not practicable and the most favorable local flood protection possibility by this means would cost about twice as much as the prospective benefits. Reservoir control, however, is entirely practicable and at least four sites are available where storage can be provided economically, either for flood control alone or for combined flood control and power storage developments. Although a reservoir system which would eliminate about 80 per cent of the estimated possible annual flood damage is entirely practicable, the cost of such a system would not be justified by the prospective benefits at the present time.

30. Conclusions. - Flood control by means of reservoirs, either for flood control alone or for combined flood control and power storage, is entirely practicable in this basin but complete protection by this means is not economically justified at the present time. It is possible, however, that partial protection may be warranted. It is also possible that, when and if further development takes place in the

valley, the need and justification for flood control may increase. Although local flood protection by means of river walls and channel improvements is not warranted, it is believed that much can be done to alleviate local flood problems by the reconstruction, repair, or removal of existing dams, bridges and buildings which now form obstructions to flood flows. Such improvements could be undertaken economically when a structure has reached the end of its economic or physical life, or when reconstruction is required for some purpose other than for flood control alone. It is also believed that a measure of flood protection can be realized by continuation and encouragement of the purposeful control of existing storage whenever hydrological conditions indicate a probable flood situation.

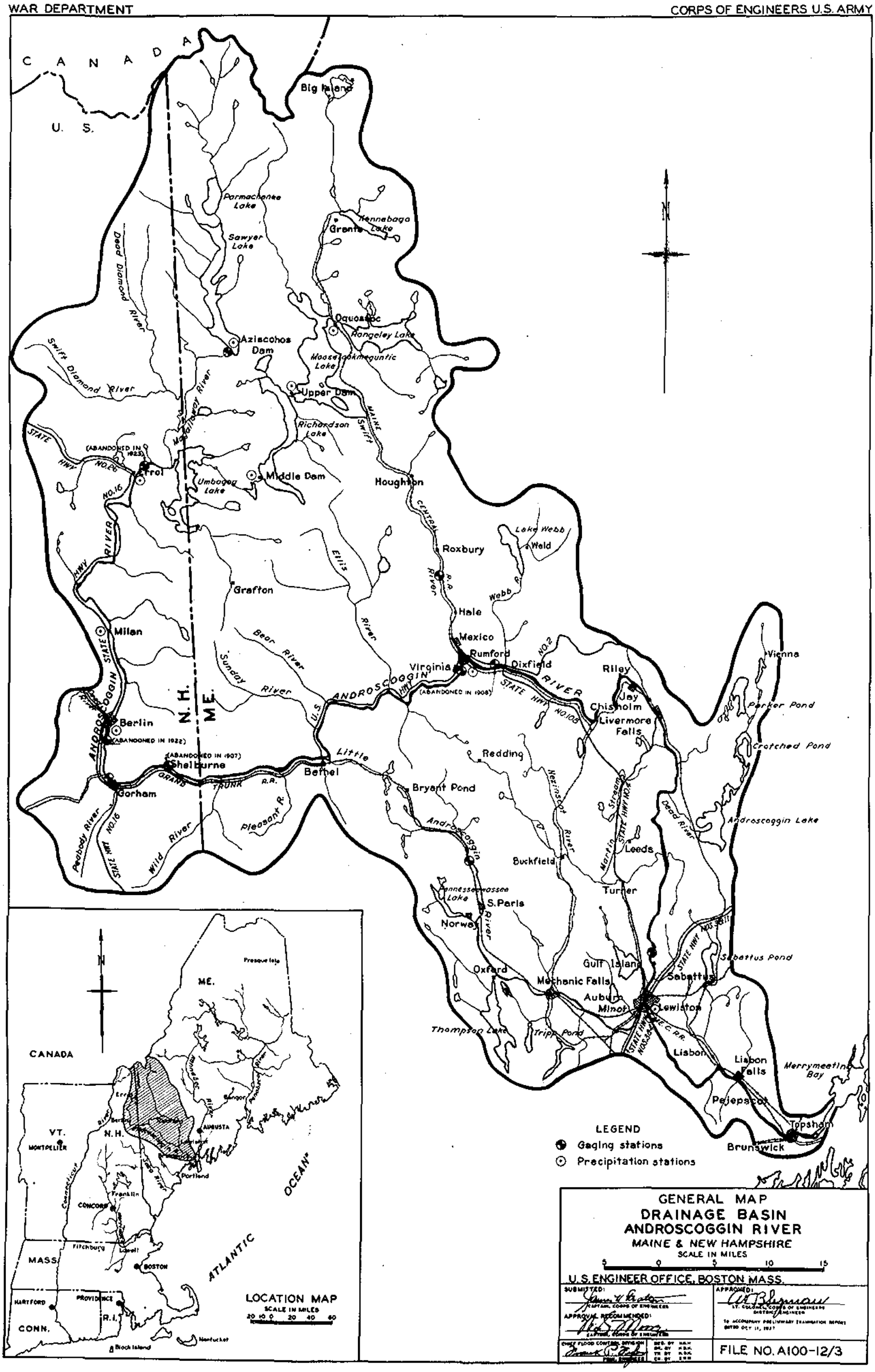
31. Recommendations. - It is recommended that a survey be made to determine the extent of flood protection by means of reservoirs which can be justified. It is also recommended that the states be encouraged to control the development along the river with a view to eliminating improper clearances and encroachments on the river channel and to coordinate the operation of existing storage reservoirs so as to achieve the maximum flood protection consistent with the conservation requirements of the storage. It is further recommended that the flood-warning and flood-forecasting services of all agencies concerned be extended and correlated through the United States Weather Bureau in order that improved forecasts and warnings may be provided.

A. K. B. Lyman
Lt. Col., Corps of Engineers
District Engineer

Inclos:
Map of Androscoggin Basin

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY



WAR DEPARTMENT
OFFICE OF DIVISION ENGINEER
NORTH ATLANTIC DIVISION
Room 1400, 80 Broad Street,
NEW YORK, N. Y.

Androscoggin R. 2/3.15 December 17, 1937.

SUBJECT: Report on preliminary examination of the Androscoggin River, Maine and New Hampshire, for Flood Control.

TO: The Chief of Engineers, U. S. Army.

SYLLABUS

The Division Engineer finds that the Androscoggin River is subject to floods. Complete flood protection can be provided by a system of reservoirs and extensive local protection works. Complete flood protection is not economically justified at the present time. Partial flood protection can be provided by means of reservoir control. It is recommended that a survey be made to determine the possibility of providing flood control in the Androscoggin basin.

1. AUTHORITY. - This report is submitted in compliance with two Acts as follows: (1) Section 6 of the Flood Control Act (Public No. 738 - 74th Congress), approved June 22, 1936, which reads in part as follows:

> "The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control at the following named localities * * * * * * * Androscoggin River, Maine, * * *"

(2) An Act (Public No. 812 - 74th Congress) approved June 25, 1936, which reads in part as follows:

> "That the Secretary of War is hereby authorized and directed to cause a preliminary examination to be made of the Androscoggin River and its tributaries in the States of Maine and New Hampshire, with a view to the control of their floods, * * *"

2. PRIOR REPORTS. - The Engineer Department has made two prior reports involving flood control on this stream. They are (1) the "308" report published as House Document No. 646 - 71st Congress, 3d session, and (2) the review thereof, dated December 30, 1936, made pursuant to resolutions of the Committee on Commerce of the U. S. Senate and the

Committee on Flood Control of the House of Representatives. This review report has not been printed. This report of preliminary examination contains pertinent data included in the review report.

3. EXISTING PROJECT. - There are no existing or prior projects for flood control on the Androscoggin River.

4. DESCRIPTION. - The watershed lies in western Maine and northeastern New Hampshire. It has a length of 110 miles and a maximum width of 55 miles. The total drainage area is 3,470 square miles. Roughly, 80% of the drainage area is in Maine and the remainder in New Hampshire. About 143 square miles of the watershed are occupied by lakes and ponds.

5. The region is blanketed with deep glacial overburden deposited upon the pre-glacial bedrock valley system. Bedrock is exposed in numerous short channel reaches in the high hills and mountains. The rock formations are predominately granite, schist, and gneiss, with occasional areas of slate and other metamorphic rock. The overburden is mainly gravelly, silty sands.

6. The upper portion of the basin is rough, mountainous, and almost entirely covered with forests. The lower portions have low, partly wooded hills, considerable cultivated land, lakes, and swamp area.

7. The total population of the basin in 1930 was about 150,000. The six largest cities in the basin are located on the main stream. They have populations ranging from approximately 4,000 to 35,000. The lower part of the basin has good highways and is served by the Maine Central and Grand Trunk Railroads. There is a large volume of manufacturing in this section. The principal products are cotton goods, pulp and paper products.

8. MAIN STREAM. - The Androscoggin River rises at the Canadian border near the Maine-New Hampshire boundary at an elevation of about 2,900 feet. It flows in a general southeasterly direction for about 200 miles to tidewater at Brunswick, Maine. The stream has an average slope

of about 13 feet per mile. Much of the fall is concentrated near Berlin, New Hampshire and at Rumford, Maine.

9. TRIBUTARIES. - The principal tributaries of the Androscoggin River are as follows:

Stream	Drainage Area Square Miles	Miles from Mouth to Tidewater
Magalloway	500	165
Swift	135	82
Webb	125	75
Dead	100	46
Nezinscot	275	38
Little Androscoggin	380	24

10. DEVELOPMENT OF WATER RESOURCES. - The Androscoggin River has been very highly developed for power. There are 28 installations on the main stream totalling 239,873 horsepower utilizing 775 feet of head. There are 14 installations on the tributaries totalling 6,596 horsepower utilizing 310 feet of head. The basin has been equally well developed for storage. The existing controlled storage capacity, mostly contained in the large natural lakes in the upper basin, is about 740,000 acre feet. About 678,000 acre feet of this storage is in the 1,095 square miles above Errol, New Hampshire. This portion of the basin, amounting to about 32% of the total area, is controlled well by this storage.

11. HYDROLOGY. - The mean monthly temperatures vary from 16.0° F. in January to 68.0° F. in July. The mean annual temperature is 42.7° F. The mean annual precipitation is 39.4 inches. The equivalent run-off at Rumford, Maine, drainage area 2,090 square miles, is 22.65 inches. The annual snow fall varies from about 77 inches at the coast to 130 inches in the headwaters.

12. Two general types of storms occur over the Androscoggin basin. These are (1) continental storms and (2) tropical hurricanes. The con-

tinental storms occur throughout the year. They account for the unusually uniform distribution of average monthly rainfall. The tropical hurricanes, accompanied by severe rains, generally occur in the summer and early fall seasons when the ground is dry. The resulting run-off is correspondingly small. The most severe floods in the basin are caused by general storms accompanied by warm temperatures and heavy rainfall on a snow-covered watershed.

13. <u>FLOOD CHARACTERISTICS</u>. - The existing storage in the Androscoggin basin exercises some degree of control over about 40 per cent of the drainage area. This storage is effective in reducing flood stages for ordinary floods. It is not sufficient to prevent damages from extreme floods. Snow is usually a contributing factor to spring floods in this basin and it may be the principal cause. Ice may be an important factor in spring floods. Generally, the ice in the lower river moves out before that in the upper reaches breaks up on account of the southerly direction of flow of the stream. When the spring break-up occurs early ice jams are likely to form at obstructions in the river. High stages result above these jams and a standing wave of high velocity is released on the valley below when the jams break.

14. <u>RECORD OF PAST FLOODS</u>. - The six highest floods of record at Rumford, Maine, drainage area 2,090 square miles, are as follows:

Date	Mean Daily Discharge (c.f.s.)
March 19, 1936	68,300*
April 15, 1895	55,230
November 5, 1927	39,100
March 2, 1896	39,010
May 18, 1893	38,060
March 13, 1936	35,600**

* Instantaneous peak discharge 74,000 c.f.s.

** Instantaneous peak discharge 38,200 c.f.s.

15. FLOOD FREQUENCY. - In the Androscoggin basin floods occur more frequently in the spring than in any other season of the year. During the period of record from 1893 to 1936 at Rumford, Maine, there were eighteen floods with peak discharges greater than the peak discharge of the average annual flood. Six of these floods occurred in April alone and twelve occurred during the months of March, April and May. The computed frequency for discharges at Rumford, Maine, is as follows:

Period	Average discharge for one day in c.f.s.
Once in 1 year	20,000
Once in 10 years	38,000
Once in 50 years	54,000
Once in 75 years	59,000
Once in 100 years	62,000

Very rare floods with peak discharges approaching 90,000 c.f.s. may be expected.

16. FLOOD LOSSES. - The flood of March 1936 was the greatest of record in the Androscoggin basin. The flood was caused by a succession of two general storms within a period of eleven days. Rainfall for the eleven day period was heavy throughout New England. It varied from a few inches along the coast to a maximum of about 20 inches in the White Mountains. Several towns were isolated for from one to four days as railroad, highway, telephone, and telegraph facilities were disrupted. Several towns were temporarily without light, power and water. Eighteen bridges were wholly or partially destroyed and ten others were damaged. The depth of water in the flooded area varied greatly. In the towns and cities a few principal streets were covered to depths of from one to five feet. In Brunswick, Maine, depths as great as 15 feet were reported. About 2,000 buildings were affected by the flood. About 6,000 people were temporarily homeless and four lives were lost.

17. The total damages resulting from the March 1936 flood amounted to $4,392,000. Of this amount $4,232,000, or 96 per cent, occurred in Maine and the remainder, or only 4 per cent, in New Hampshire. There is no reliable record of the losses that resulted from the floods of 1896 and 1927. Losses from the latter flood were severe but they did not reach the magnitude of the losses resulting from the 1936 flood. The annual damages from floods in that portion of the basin lying below prospective reservoir sites were determined as $453,500. This amount was considered as the basis for the justification of possible flood control measures.

18. The area subject to flooding in the basin is not large. A large amount of industrial property located immediately adjacent to the normal river channel is subject to damage from extreme floods. The commercial sections of several communities located near the waterfront are seriously affected by extreme floods. Inundation of agricultural land is not serious as floods usually occur in the spring before crops are planted. In general the benefits from adequate flood control measures in the basin would be confined to the elimination of damages to existing developments. Benefits from increased value and productivity of the area subject to flooding would be negligible.

19. <u>POSSIBLE METHODS OF FLOOD CONTROL</u>. - The most desirable method of obtaining general flood relief in this basin is by means of reservoirs. Diversion of flood flows is not practicable. Channel improvements and flood protection by levees are not applicable for general flood protection throughout the valley on account of the excessive cost, and the problem of tributaries. These methods can be considered for positive local protection as supplements to possible reservoir control.

20. There are several favorable sites in the basin for flood control reservoirs. In conjunction with existing controlled storage these sites would control about 75 per cent of the watershed area. This is an unusually large degree of control. It would afford appreciable reductions

in flood stages at the principal damage centers and eliminate approximately 80 per cent of the estimated annual flood damage. Of the 75 per cent of the watershed area controlled, the flood control reservoirs would provide about 42 per cent and existing power storage about 33 per cent. To be effective, the operation of the flood control storage would have to be coordinated with the operation of the existing power storage.

21. An investigation was made at thirteen damage centers to determine the possibility of providing local protection works. The cost of full protection would exceed the benefits which could be realized. Protection works supplementing the reduction in flood heights obtained by prospective reservoir control may be justified.

22. Some alleviation of the flood situation in many localities can be secured by the exercise of State or local zoning control at the time present objectionable structures are replaced because of obsolescence or deterioration.

23. POWER DEVELOPMENT IN CONJUNCTION WITH RESERVOIR CONTROL. - The export of hydro-electric power from the State of Maine is prohibited by law. Present local needs are supplied well by existing installations and inter-connections with other systems. There is a possibility that at least one of the sites considered in this report could be developed for flood control and power. In view of the excess generating capacity now available, a combined development would not be practicable at the present time.

24. VIEWS AND RECOMMENDATIONS OF THE DISTRICT ENGINEER. - The District Engineer finds that flood control, either alone or in conjunction with power developments, by means of reservoirs is practicable. He finds that partial protection may be economically justified. Local flood problems may be alleviated by exercising State or local zoning control at the time existing structures that form obstructions to flood flows are replaced due to obsolescence or deterioration. The District Engineer recom-

mends a survey to determine the extent of flood protection which can be justified.

25. VIEWS OF THE ACTING DIVISION ENGINEER. - The Acting Division Engineer concurs with the views and recommendations of the District Engineer. The extent of flood loss in the basin warrants accurate determination of the justifiable extent of federal participation in flood control measures. A continuance of the study under a survey report should develop further the possibilities of requirements of local cooperation from State and municipal authorities in the form of zoning in the interest of reduction of flood heights and flood damages through elimination of channel obstructions.

26. RECOMMENDATION. - It is recommended that a survey be made to determine the possibility of providing flood control for the Androscoggin River, Maine and New Hampshire.

JOHN C. H. LEE,
Lieut. Colonel, Corps of Engineers,
Acting Division Engineer.

Incl.accpg.:
2/3.14, in quad.

4867/2
Subject: Androscoggin River, Maine and New Hampshire - Flood Control.

2nd Ind.

The Board of Engineers for Rivers and Harbors, Washington, D. C., January 20, 1938 - To the Chief of Engineers, U. S. Army.

1. The Board concurs with the division engineer in recommending a survey to determine the advisability and cost of improvement and the local cooperation required.

For the Board:

R. A. Wheeler,
Lieutenant Colonel, Corps of Engineers,
Resident Member.

E.D. 7402(Androscoggin River, Maine)15,
15/1 and Ser. 17 accompg.

WAR DEPARTMENT

OFFICE OF THE CHIEF OF ENGINEERS

WASHINGTON, D. C.

ADDRESS REPLY TO
[C]IEF OF ENGINEERS, U. S. ARMY
WASHINGTON 25, D. C.

[RE]FER TO FILE No. ENGKW

28 May 1947

SUBJECT: Review of reports on and a preliminary examination and survey of Androscoggin River, Maine and New Hampshire

TO: The Division Engineer
New England Division
Corps of Engineers
BOSTON, MASS.

The report on a review of reports on and a preliminary examination and survey of Androscoggin River, Maine and New Hampshire, was transmitted to Congress by the Secretary of War on 30 April 1947. Duplicate copies of the letters of transmittal are inclosed for the files of your office. Copies of the reports of the Chief of Engineers as signed and dated are also inclosed. Copies of the report of the Board of Engineers for Rivers and Harbors and letter containing the comments of the Governor of Maine have previously been furnished your office.

BY ORDER OF THE CHIEF OF ENGINEERS:

J. L. PERSON
Colonel, Corps of Engineers
Deputy Chief of Civil Works
for Flood Control

4 Inclosures: (in dup)
1. Cy of trans ltr to The Speaker, 30 Apr '47
2. Cy of trans ltr to Chmn, Sen Comm on Pub Wks, 30 Apr '47
3. Cy of CE Report to FC Comm, 30 Nov '44
4. Cy of CE Report to Sen Comm, 30 Nov '44

WAR DEPARTMENT
WASHINGTON

ENGKW APR 30 1947

The Speaker of the

House of Representatives

Dear Mr. Speaker:

I am transmitting herewith a report dated November 30, 1944, from the Chief of Engineers, United States Army, together with accompanying papers, on a review of reports on and a preliminary examination and survey of Androscoggin River, Maine and New Hampshire, requested by resolutions of the Committee on Flood Control, House of Representatives, adopted on March 27, 1936, and the Committee on Commerce, United States Senate, adopted on March 28, 1936; and also authorized by the Flood Control Act approved on June 22, 1936, and by an Act of Congress approved on June 25, 1936.

In accordance with Section 1 of Public Law 534, Seventy-eighth Congress, copies of the report of the Chief of Engineers were furnished the Governors of the States of Maine and New Hampshire. The views of the State of Maine are set forth in the inclosed communication. The Governor of New Hampshire acknowledged receipt of the report on July 20, 1945, and to date has furnished no written views or recommendations with respect thereto.

The Bureau of the Budget advises that while there is no objection to submission of the report to Congress, authorization of the improvement, which the Chief of Engineers recommends be not undertaken at this time, is not in accord with the program of the President.

Sincerely yours,

(Signed) ROBERT P. PATTERSON

Secretary of War

2 Inclosures:
1. Cy of ltr fr Gov of Maine, July 25, 1945
2. Report with accompanying papers

WAR DEPARTMENT

OFFICE OF THE CHIEF OF ENGINEERS

WASHINGTON

CE SPEKW NOV 30 1944

The Chairman,
Committee on Flood Control,
House of Representatives, U. S.,
Washington, D. C.

My dear Mr. Chairman:

1. The Committee on Flood Control of the House of Representatives, by resolution adopted March 27, 1936, requested the Board of Engineers for Rivers and Harbors to report to this Committee at the earliest practicable date, the results of the additional studies and investigations made on the Androscoggin River, to take into account important changes in economic factors, additional stream flow records, or factual data developed as a result of the recent severe flood, with a view to revising the report on this river printed as House Document No. 646, 71st Congress, 3rd session. Under date of March 28, 1936, the Committee on Commerce of the United States Senate requested the Board of Engineers for Rivers and Harbors to review the report on Androscoggin River, Maine, submitted in House Document No. 646, 71st Congress, 3rd session, with a view to determining whether any modification of the recommendations contained therein is deemed advisable as a result of the recent severe floods. I inclose the report of the Board in response thereto. It is also in review of the reports on preliminary examination and survey for flood control on "Androscoggin River, Maine," authorized by the Flood Control Act of June 22, 1936, and of the reports on preliminary examination of the "Androscoggin River, Maine and New Hampshire," authorized by the Act of June 25, 1936, under the provisions of the Act of March 1, 1917.

2. After full consideration of the reports secured from the district and division engineers, the Board recommends that no improvement of Androscoggin River, Maine and New Hampshire, for flood control be undertaken by the United States at the present time.

3. After due consideration of these reports, I concur in the views of the Board.

Very truly yours,

E. Reybold,
Major General,
Chief of Engineers.